

GENERAL SCIENCE

SNYDER



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GENERAL SCIENCE

BY

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PREFACE

In this book the author's first aim is to make science a living thing to pupils. The text is simple and readable. Picturesque aspects of the subject are used to awaken interest in its practical application.

General science has long since risen to the dignity of independence. It is a unit in itself and its primary objectives are (1) to furnish a fund of scientific information that will help pupils to interpret their environment; (2) to inculcate in young students the habit of thinking from cause to effect and back from effect to cause.

Scientific problems are studied in their relation to human welfare. The usefulness of science is shown by innumerable applications. Throughout the book the relations between science and civic welfare are repeatedly brought out, but the book remains primarily a textbook of science.

The distinguishing feature of the organization of the text material lies in the order of topics. Chapter follows chapter logically. The large units in each chapter are closely related, and the topics in each unit follow in careful sequence. The treatment is as coherent as a story. In unit and section headings scientific terminology has been avoided.

If the introduction to each of the nineteen chapters be read in succession, the trail of thought throughout the book will make itself apparent. The beginning of each chapter is a combined review and survey outlining the coming chapter against the background of previous study.

The recommendations of the well-known Report on the

Reorganization of Science in secondary schools have been followed.

The book is full of interesting equipment for teaching. Thought questions are distributed throughout the text and are made simple enough really to encourage thought.

Scores of new illustrations and simple diagrams have been introduced. Careful explanatory captions link the pictures to the text. Comprehensive summaries and review questions occur at the end of each chapter.

W. H. S.

March 30, 1925.

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The book begins with a panorama of the open sky. From it the pupil learns something of the universe, of which our earth forms so small a part. He also learns the first great law of science, that "order is Heaven's first Law."

This chapter pictures the universe in motion, and explains the results to us on earth of the tremendous movements of heavenly bodies in space.

Chapter III answers the question: "What is it all made of?"—a brief discussion of the forms and composition of matter.

Chapter IV answers the question: "What makes it go?" This is a brief discussion of the source and nature of all energy.

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Chapter VI is wholly concerned with the control and uses of heat in the home. Materials for clothing, the coal range, kitchen utensils, the fireless cooker, the refrigerator, the thermos bottle, fireplaces and heating stoves; hot air, hot water, and steam heating plants; home construction, and ventilation are among the topics fully treated.

This is a very short chapter that tells the interesting story of the effect of heat on the earth's crust. The two agents that have had most to do with molding the face of the earth are heat and water. This seems the place for the story of the work of heat.

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Chapter IX is devoted to water. Another basic chapter. A brief discussion of the work of water in sculpturing the earth's surface is followed naturally by a full discussion of the scientific and civic importance of forestry and flood prevention. The origin of wells and springs, the work of water as a solvent, distillation and purification of water, are among the other topics found in this chapter.

Methods of purification, clarification, and delivery of water through cities are detailed. Studies of cold storage, water transportation, water power, mill wheels, water turbines, and conservation of water power are other subjects considered in this chapter.

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CHAPTER I

THE OPEN SKY

*Go forth under the open sky and list
To Nature's teachings.*—Bryant.

"If the stars should appear one night in a thousand years, how men would believe and adore and preserve for many generations the remembrance of the city of God which had been shown."* But the stars are such common objects that many of us pay little attention to them.

Because they are spread out to view on any clear night, they offer a convenient field of observation. Here we may well begin our study of science in order to learn something of the universe, of which our earth forms so small a part. Certainly no study can serve better than that of the starry skies to convince us at the outset that "order is Heaven's first law."

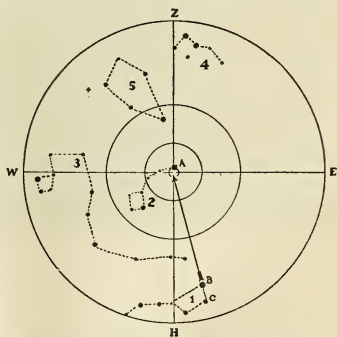


FIGURE 1.—DIAGRAM SHOWING CONSTELLATIONS IN THE NORTHERN SKY

A, Polaris or North Star; 1, Big Dipper; B and C, Pointers; 2, Little Dipper; 3, Dragon; 4, Cassiopeia's Chair; 5, Cepheus.

*Emerson.

I. GROUPINGS AND APPARENT MOVEMENTS OF THE STARS

Star-Groups.—A glance at the evening sky makes one wonder how the earliest observers ever began to chart this “sea of stars.” Carlyle, in bewilderment and impatience, once complained: “Why did not somebody teach me the constellations and make me at home in the starry heavens, which are always overhead and which I don’t half-know to this day!”



STAR MAP, NORTHERN SKY

September 1, midnight; September 15, 11 P. M.; October 1, 10 P. M.

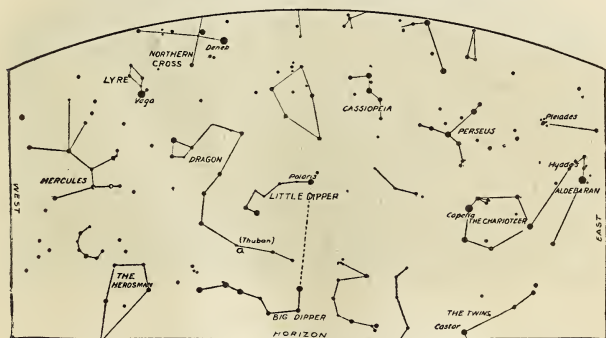
Assignment.—On a clear evening, locate the group of seven bright stars known as the Big Dipper. The position of this group varies with the seasons in the circuit of the *northern sky*. Figure 1, showing the Big Dipper down near the horizon (H) indicates its position on November 20, at 8 P. M. Six months later, May 20, at 8 P. M., it will be found at its highest point (Z) not far north of the zenith (the point of the sky directly overhead). On February 20, it will be found half-way up, at E, in the eastern portion of the northern sky; and on August 20, it will be found at W, half-way down the western circuit of its arc.

Assignment.—When you have located the Big Dipper, pick out the two stars that form the edge of the “bowl” farthest from the

"handle." (B C, Figure 1.) Let your eye extend the line formed by these two stars as indicated in Figure 1, and it will lead almost directly to *Polaris*, or the *North Star*. This is a fairly bright star in the north, about midway between the zenith and the horizon.

To identify *Polaris* further, trace the Little Dipper (2, Figure 1). The North Star forms the tip end of the "handle."

Probably the first careful watchers of the sky were the early shepherds of Asia. Long observations convinced them that the stars never change their positions in rela-



KEY TO STAR MAP, NORTHERN SKY

September 1, midnight; September 15, 11 P. M.; October 1, 10 P. M.

tion to each other. And so they came to recognize unchanging groups of stars. Just as we sometimes try to distinguish pictures in the glowing coals of a grate fire, so they traced rough resemblances between these star-groups, or *constellations*, and the animals with which they were familiar. Thus we have the constellations of the Great Bear, the Little Bear, the Great Dog, the Little Dog, the Bull, the Lion, the Eagle, etc.

The Greeks named other constellations after their heroes. It is disappointing to see how little these star-

groups resemble the objects after which they are named, but we still retain the groupings and their names for convenience in locating individual stars.

The Big Dipper is a modern grouping with a modern name. The four stars of the bowl are included in a constellation of more than thirty stars to which the ancients gave the name of the Great Bear. The Great Bear is difficult to trace, and even when traced it does not present



STAR MAP, SOUTHERN SKY

November 1, midnight; November 15, 11 P. M.; December 1, 10 P. M.

a very convincing outline of a bear. In the same way, the modern Little Dipper is made up of a few stars which the ancients included in the constellation of the Little Bear. The Big Dipper and the Little Dipper are probably the best known of all the constellations because they are always in view on a clear night in the northern heavens.

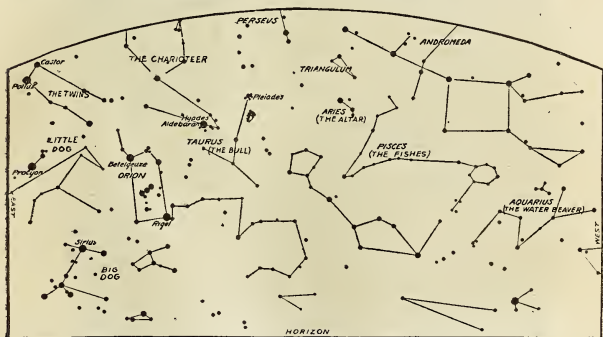
Apparent Movements of the Stars.—Assignment (A).—Early on a clear evening, locate the Big Dipper. To a tree, fence, or post, nail a straight-edged ruler in such position that you can sight along its straight, narrow edge one of the bright stars of that constellation.

(B) Nail another ruler to some stationary object, in such position

that you can sight the North Star in line with the straight edge of the ruler.

Two or more hours later in the evening, sight along the edge of the first ruler and see if the same bright star of the Big Dipper is still in line with it.

If it can no longer be sighted along the ruler's edge, is its new position to the right or left of its former position? Above or below? If you were told that the Dipper was moving in a circular path around the North Star, in which direction should you say it was circling? Draw a circle and indicate the direction with arrows.



KEY TO STAR MAP, SOUTHERN SKY

November 1, midnight; November 15, 11 P. M.; December 1, 10 P. M.

Now sight along the second ruler's edge. Is the North Star apparently in about the same position it occupied when you first sighted it? If not, do you notice as great a change of position as in the case of the star of the Dipper?

Of all the stars you may observe, only one; the North Star, seems to remain almost exactly in its place.

"The skies are painted with unnumbered sparks,
They are all fire and every one doth shine;
But there's but one in all doth hold his place."*

*Shakespeare's "Julius Caesar."

While the stars never seem to change their positions in relation to each other, yet all of them except the North Star seem to be ever moving in fixed order around or across the skies. To us in the northern hemisphere, the



"NORTH POLE OF THE HEAVENS"

A telescope was held pointed at the pole of the heavens for two hours and twenty minutes. The rotation of the earth caused the stars to register as white lines, as if moving in circles.

stars in the northern sky seem to circle about the North Star once in every twenty-four hours. The other stars appear to rise in the east and to set in the west just as the sun does. Modern scientists have proved in many ways that the earth is turning from west to east on an axis.

This motion is imperceptible to us, and so the stars and sun and moon seem to be passing overhead in a constant procession from east to west.

The "North Pole of the Heavens".—The points on the earth's surface through which its axis passes are called the *poles*. At these points, just as at the center of the hub of a wheel, there is the least motion. If we imagine this axis extended far enough into space, it would, at the present time, nearly strike the North Star. This star may therefore, be thought of as the north pole of the heavens, at which there is the least apparent motion of the stars.

If an observer could stand at the North Pole and watch the stars for twenty-four hours, the North Star would remain constantly overhead. All the other stars would be like lights fixed in a slowly revolving dome, with its center overhead, and its lower edges on the horizon. In the twenty-four hour watch the stars lowest down would seem to make the entire circuit of the horizon, while the stars nearer to Polaris would seem to travel in smaller circles.

Careful measurements by astronomers show that Polaris is not at the exact pole of the heavens, but the circle it makes about the imaginary center is so small that the unaided eye can not easily detect any variation in its position.

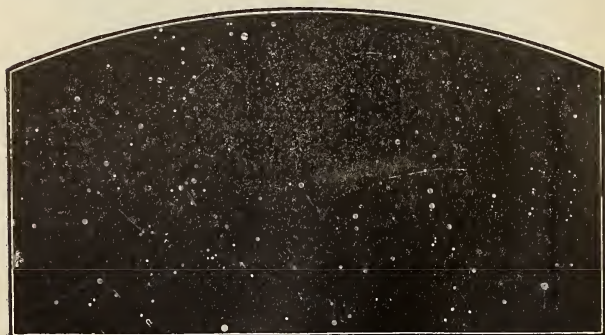
Any star that appears to move across the heavens comes into an observed position about four minutes earlier each day. This daily variation is caused by the fact that the earth has made a day's journey in its path around the sun, and is in a different position in its orbit.

If it were possible for us to observe the Big Dipper every night at the same time, for a year—beginning, for example, on November 20 (Figure 1)—we should find that it changed its apparent position every night. By No-

vember 20 of the following year, it would seem to have completed one extra circuit about the North Star.

The annual circuit the Big Dipper seems to make about the pole of the heavens is really caused by the complete trip the earth makes in its orbit about the sun.

Because of the revolution of the earth about the sun, the panorama of the stars in the east, west, and south



STAR MAP, NORTHERN SKY

January 15, 11 P. M.; February 1, 10 P. M.; February 15, 9 P. M.

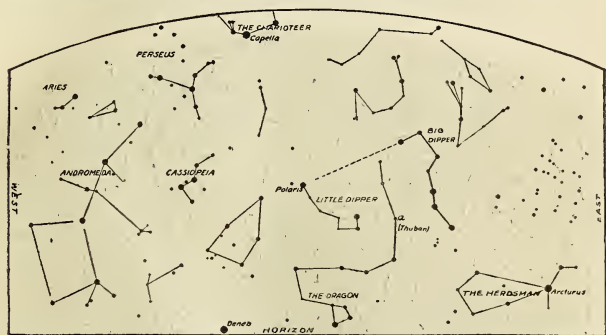
changes with the seasons. The stars that seem to rise in the east and set in the west can be seen by us only about half the year. The remainder of the time, they are above us during the day, when the brighter light of the sun blots them out.

Voluntary Project.—To locate important stars.—Northern Sky.—Look at the star-map and key, pages 2 and 3, which represent the positions of the stars in the northern sky on September 15, at 11 P. M., of any year. Since the stars seem to come into observed positions about four minutes earlier each day, this diagram also represents the northern sky on September 1 at midnight, on October 1 at 10 o'clock, on October 15 at 9 o'clock, etc.

A.—Locate the Dragon on the key, then on the star-map, and finally see if you can trace it in the northern sky.

B.—We know the two stars of the Big Dipper which are called the pointers. Now center your attention on the two stars that form the other edge of the "bowl," the edge that is a continuation of the "handle." These two stars point toward the Dragon. The nearest star in the tail of the Dragon toward which they point directly (a) is the pole-star of 4000 years ago. Its ancient name was Thuban.

C.—Follow the line of these three stars through the Dragon. The line will pass through another star of the Dragon's tail, through two



KEY TO STAR MAP, NORTHERN SKY

January 15, 11 P. M.; February 1, 10 P. M.; February 15, 9 P. M.

stars of the Dragon's head, and will extend almost directly toward Vega, one of the brightest stars in the northern heavens. Astronomers calculate that 12,000 years from now, this will be the pole-star of the earth.

D.—Locate the constellation of Cassiopeia's Chair. It is about the same apparent distance from the North Star as the Big Dipper and always on the opposite side of Polaris from that constellation. Above the North Star, it has the shape of a sprawling M. When it is below Polaris, it is inverted into a W-shaped cluster.

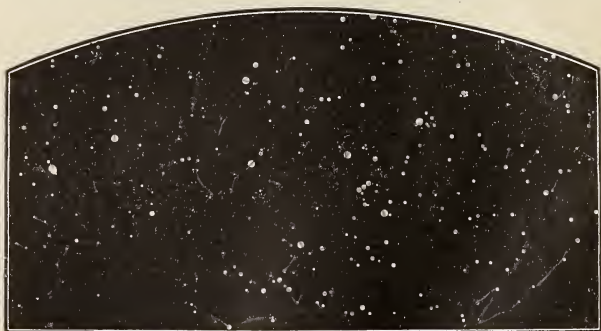
Note.—If you make these observations in the middle of February, remember the changed position of the Big Dipper and get your bearings from the pointing stars of its bowl. Vega will be below the horizon. See star-map and key, pages 8 and 9.

Southern Sky.—The most beautiful combinations of stars and star-groups in the southern skies begin to be visible at a reasonable hour about the middle of November. The sky-map and

key (pages 4 and 5) indicate the positions of the stars as the observer faces south on November 15, at 11 P. M. (December 1, at 10 P. M.; December 15, at 9 P. M.; etc.). To see the stars in this position on September 15, set your alarm-clock for 3 o'clock in the morning.

A.—Well above the eastern horizon is Orion, the famed hunter of Greek mythology—probably the most beautiful and impressive constellation in the heavens. Read the story of this hero in Greek mythology.

The oblong figure is his body. The three bright stars which run



STAR MAP, SOUTHERN SKY

January 15, 11 P. M.; February 1, 10 P. M.; February 15, 9 P. M.

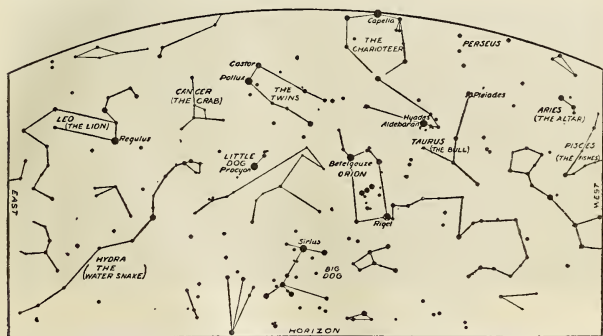
diagonally through the body form the hunter's belt, from which is suspended his sword. The great star which forms the right shoulder, from which the uplifted arm rises, is Betelgeuse, a giant star. The lower left-hand star (diagonally across the oblong figure from Betelgeuse) is Rigel.

B.—If you will follow the direction of the three bright stars forming the belt, you will trace a line which extends down the eastern horizon toward Sirius, the brightest star in our heavens. This is known as the Dog-Star, in the constellation of the Great Dog, which faithfully follows the great hunter across the winter sky.

C.—Following the line of these three stars of the hunter's belt up the sky toward the west, the eye comes to a red-hued star, called Aldebaran, in a group known as the *Hyades*. The line continued leads to one of the most beautiful constellations in the heavens, called the *Pleiades*. This group of seven stars is mentioned in the writings

and traditions of more peoples than any other group of stars in the heavens. It was the "seven sisters" of the Greeks and the "seven brothers" of the North American Indians. The Babylonians, the Persians, and the Egyptians had their names for it, as did the Aztecs, the Australian tribes, and the South Sea Islanders. See the references to it in the Bible: Job ix, 9; xxxviii, 31; and Amos v, 8.

By February 1, at 10 P. M., Sirius will be almost directly in the south, and Orion will be leading it on the way to the western horizon. See star-map and key, pages 10 and 11.



KEY TO STAR MAP, SOUTHERN SKY

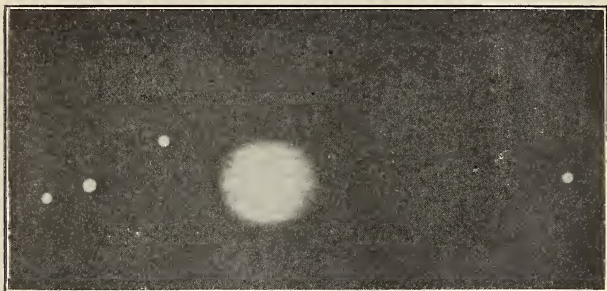
January 15, 11 P. M.; February 1, 10 P. M.; February 15, 9 P. M.

II. OUR SOLAR FAMILY

The Wanderers.—If we carefully observe the myriads of bright points that dot the sky at night, we shall see that almost all of them shine with a twinkling light. These are the stars. At times, among the countless twinkling lights, we see a very bright starlike body which *usually* gives a steady light like that of the moon. When the positions of one of these steady-shining bodies are carefully observed for weeks or months, the body will be found to be continually changing its place among the stars, while the groupings of the stars themselves do not appear to change.

Such a bright steady-shining heavenly body is called a *planet*, from the Greek word meaning *wanderer*. It belongs to a family of heavenly bodies, of which the earth is one, that make regular circuits around the sun.

Occasionally, on a very calm, clear night, neither the stars nor the planets twinkle. On other nights, not only the stars but the bright planets seem to twinkle. This is



JUPITER AND ITS FOUR LARGEST SATELLITES

Photographed at Lowell Observatory. These moons of Jupiter were the first objects discovered by means of a telescope—by Galileo, January 7, 1610. The smallest of these satellites is about the size of our moon. The largest moon has nearly twice the diameter of ours. See page 30.

because of disturbed conditions of the atmosphere. On such nights the naked eye can hardly distinguish a star from a planet. But if a small telescope or a pair of binoculars is used, a “wanderer” can be identified immediately. A bright planet seen through even a small telescope will increase in brightness and in size, and will take on a definitely spherical shape. The stars are so far away that if they are observed through a telescope, the only difference is an increase in brightness. They do not increase in size, nor take on any definite outline.

The planets are by far the nearest of all the star-like bodies, although the earth’s nearest neighbor, the planet

Venus, never comes nearer than 23 millions of miles. The most distant planet, Neptune, travels in a path, or *orbit*, about the sun that is 2700 millions of miles farther away from the sun than the earth's orbit. But Neptune is a close neighbor as compared with the nearest of the stars.

Voluntary Project.—Consult a current almanac or "The Monthly Evening Star-Map"* and see if any planet is now visible. If so, locate it among the stars, and watch it from night to night for a month.

Size and Appearance of the Planets.—Of the eight planets that revolve about the sun, the four most distant are larger than the earth. Of the four whose orbits lie closest to the sun, the earth is the largest. The planets in the order of their distances from the sun are Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune. In the space between Mars and Jupiter, there has been found a group of small bodies which are called *planetoids* or *asteroids*. (Figure 2.)

The three planets which shine most brightly for us are Jupiter, Venus, and Mars. Jupiter, the largest of the planets, takes its name from the king of the Roman gods. It is greater in bulk, the space it occupies, than all the other planets combined. To the naked eye, Venus is

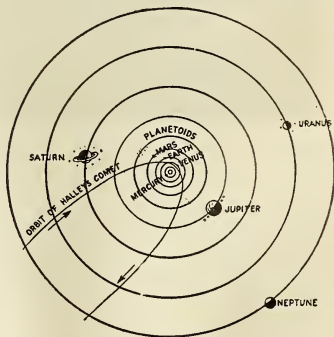
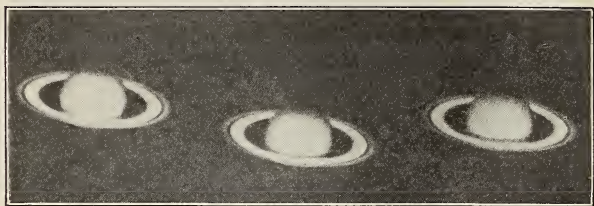


FIGURE 2.—DIAGRAM OF SOLAR SYSTEM
Showing roughly the relative positions of the
various planets and their satellites.

* A little journal for amateur astronomers, published by Leon Barritt, 367 Fulton Street, Brooklyn, N. Y.

the most magnificent planet in the solar system, exceeding in light and beauty the brightest star. It is therefore called by the name of the Roman goddess of beauty. Mars shines with a reddish brown color, and on this account bears the name of the Roman god of war. Through the telescope, it sometimes shows very plain markings, called "canals," and a white disc that some astronomers regard as a cap of polar snow.

Venus and Mars are the only two planets on which it seems possible that any life could exist. The atmos-



THREE VIEWS OF SATURN
The planet with the beautiful rings.

phere of Venus is so dense that we can make no study at all of the surface of the planet. The atmosphere of Mars is very thin, and there is probably but little water on this planet as compared with the abundance on earth. The American astronomer Lowell believed that the polar cap seen during Mars' winter marks the site of a polar sea from which a network of irrigation ditches carry water to distances as great as 3600 miles. The "canals" seen through the telescope seem to have a greenish tinge during Mars' summer. For that reason, Lowell believed that they are in reality strips of vegetation growing for miles on each side of the main irrigation ditches.

Saturn is plainly visible at times, but the bright concentric rings, composed of little moonlike bodies that

surround it and revolve about it, can be seen only with the aid of a telescope. When once in about every fifteen years Saturn is so situated that we have our best view of the broad side of these rings, the telescope reveals what is probably the most beautiful sight in the solar system.

Uranus can be singled out by the naked eye of only the most practised observer. Neptune is so far away that it cannot possibly be seen without the aid of a powerful telescope. Mercury travels so close to the sun that it is lost most of the time in the glare of sunlight.

The Sun; Its Size.—

At the center of our family of planets and smaller heavenly bodies that accompany us, is the parent sun. It is the giant controller, upon which the planets depend for their

very existence. For this reason, our sun colony is called the *solar* system, from the Latin word *sol*, meaning sun.

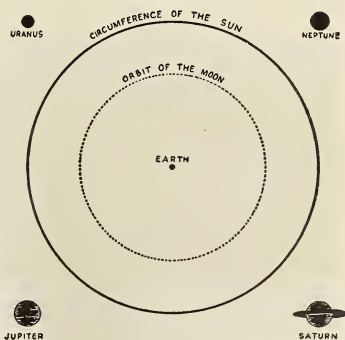


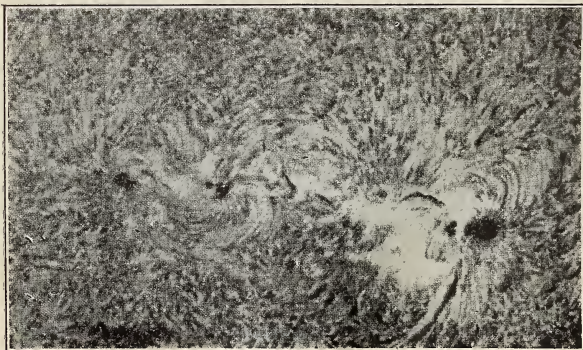
DIAGRAM COMPARING SIZE OF THE SUN AND FIVE LARGEST PLANETS

Demonstration.—Paste sheets of newspaper, or wrapping paper, together until you have a surface a little more than 54 inches square. Place this sheet on a smooth floor or work table. Drive a tack through the center of the sheet, and attach one end of a long string to the tack. To the other end of the string, 27 inches away from the tack, attach a pencil. Draw a circle on your paper, which should measure 54 inches in diameter. Now attach a colored crayon to the string, 15 inches from the tack, and draw a circle 30 inches in diameter.

Remove the tack. Trim the sheet along the circumference of the large circle. Place at the center of this circular sheet a half-inch circle of bright-colored paper. Lay a dot of white paper about $\frac{1}{8}$ of an inch in diameter at any point on the 30-inch circle.

The half-inch circle represents the earth, 8000 miles in diameter. The dot represents the moon, a little more than 2000 miles in diameter. The circle drawn with colored crayon indicates the distance of the orbit of the moon from the earth, about 240,000 miles. The large circular sheet shows the relative diameter of the sun, more than 866,000 miles.

To make a trip by fast express from San Francisco to New York requires about four days, and the average rate



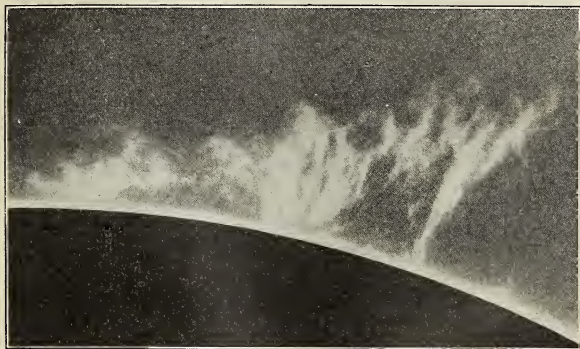
SUN SPOTS

The furiously whirling areas shown in this picture are thousands of miles in diameter.

of travel is about thirty miles an hour. If such a train could follow the line of the earth's equator at this steady rate, it could complete the circuit of the earth in a little less than thirty-five days. But if it were possible to make a similar trip around the surface of the sun, more than ten years would be required for the journey.

The Surface of the Sun.—Astronomers see the surface of the sun as a wild tumult of raging flame. The outside layers are made up wholly of incandescent gases; but the

interior, because of the enormous pressure upon it, must be either molten or solid. Stupendous eruptions and tempests of flaming vapor rend its surface, causing white-hot gases to shoot up for hundreds of thousands of miles. And yet these flames are not fire as we know it on earth. We can only make unsatisfactory guesses as to what has caused the sun's tremendous energy of heat and light for millions of years, and will cause it to continue for millions of years to come. In the unimaginable



SURFACE EXPLOSIONS ON THE SUN

These gas flames shoot thousands of miles out from the surface of the sun. They were photographed during an eclipse.

heat of the surface of the sun, the hardest substances known to man can exist only as vapors.

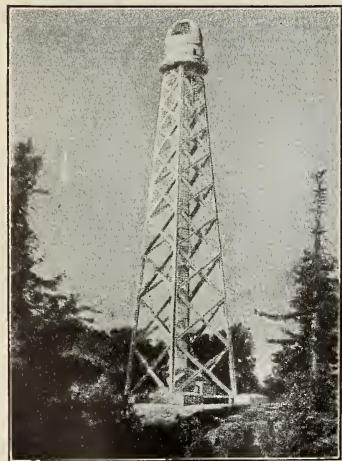
Assignment.—Look at the sun through a smoked or dark-colored glass. See if you can detect a black spot—a sun-spot—on its surface. If you can find such a spot you may be sure that it is four times the diameter of the earth, or greater. Sun-spots are seen in greatest number once about every eleven years. The next time for a maximum display is about 1928. But you may be fortunate enough to see a sun-spot at any time.

These sun-spots are furious, whirling storms of vast diameter. They often continue for long periods of time, and seem to have something to do with great electric disturbances on our earth.

The Sun's Gifts of Heat and Light.—The sun is the ruler of the solar system, not only in that it holds the planets in their orbits as they revolve about it; it also controls the activities upon the planets since it furnishes

them with their heat and light. Without the heat of the sun the earth would be a cold, barren, lifeless, inert ball of matter, and nothing more. We have developed artificial self-luminous bodies such as candles, lamps, electric lights, but none of these compares with the light given by the sun.

Of the total amount of heat radiated by the sun, the earth receives only about one two-billionth. Yet this tiny fraction of the sun's total heat furnishes practically all the energy of



MT. WILSON SOLAR OBSERVATORY

The 150-foot telescope. Probably the most effective instrument for studying the sun.

the earth. It has stored the earth's crust with coal, petroleum, and gas, from which we obtain heat, light and power. It furnishes our food, the material for our clothing, and the very trees that shelter us from its midday rays.

III. DISTANT SUNS

The Stars Are Distant Suns.—The number of stars in the heavens is estimated in hundreds of millions, although only about three thousand are visible to the naked eye. Each of these twinkling points is a sun, shining by its



GLOBULAR STAR CLUSTER

Photographed at Mt. Wilson Observatory April, 1910. A hazy speck barely visible even with the largest telescope. It contains perhaps a million stars, thousands of which are individually larger than our sun. A recently discovered star cluster is so far away that it requires 215,000 years for the light coming from it to reach us.

own light. Our sun if seen from the distance of one of the nearer stars would appear like a twinkling star.

Many of the stars are much larger than our own sun, but these giant spheres are so remote that they flicker in the evening sky like so many candles. The nearest star is probably about 25,000 billion miles away, or nearly

270,000 times as far away as our own sun. The measurement of such distances in miles means so little to the mind of man that astronomers have come to calculate distances of stars in what they call light-years. It has been proved that a ray of light travels at the inconceivable rate of



PART OF THE MILKY WAY

There are hundreds of millions of stars in the Milky Way, so thickly strewn that they appear to the eye as an irregular stream of light across the sky. The plate for this photograph was exposed ten hours and a quarter.

more than 186,000 miles a second. It therefore travels more than 16 billion miles a day or almost 6 trillion miles a year. This distance which a ray of light travels in a year is called a *light-year*.

If a ray of light could be directed along the line of the earth's equator, it would travel around the earth and back to its starting point in less than one-seventh of a second. A ray of light from the sun, about 93 million miles away,

reaches the earth in about eight minutes. But a ray of light from the *nearest bright star* requires more than four and a third years to reach us. It is, therefore, four and a third light-years distant. This star (Alpha Centauri) is not visible to us in northern latitudes. The nearest bright star we can see from our hemisphere is Sirius, the "Dog-Star" (page 10). But Sirius is so far away that almost nine years are required for its light to reach us.

Assignment.—Find the bright star Arcturus (Star-map and key, pages 8 and 9). Any time before ten o'clock about the fifteenth of September (or before nine o'clock, about the first of October) locate the Big Dipper. Pick out the two stars that form the bottom of the bowl. Let the eye follow the line formed by these two stars in the general direction of the Dipper handle. They will point westward to a very bright yellow—at times, almost reddish—star. This is Arcturus.

In the dead of winter it is below the horizon at night. But very early in the new year, it begins to re-appear on the *eastern* horizon.

About the first of February, any time after ten P. M. (February 15, after 9 P. M., or March 1, after 8 P. M.) the stars at the bottom of the bowl will be found pointing down toward Arcturus in the eastern portion of the northern sky. In midsummer it will be found high in the heavens, to the south of the zenith.

When you look at Arcturus, you are looking at a star that astronomers say is about twenty times greater in diameter than our own sun, and 7500 times greater in bulk or volume. But it is thirty-four light-years away from us. A sun the size of our own would not be visible to the naked eye at that distance. The North Star is much dimmer than Arcturus. Not size but distance accounts for this relative dimness, since Polaris is probably about 200 light-years distant. Vega, which in an earlier assignment we located in the northern sky, is forty light-years distant.

But one of the giants of the heavens that astronomers have been able to measure is Betelgeuse (page 10). By a

very delicate and complicated device perfected by an American astronomer, Professor Michelson, the diameter of this star has been recently measured. Its diameter is almost 300 times the diameter of our sun and its volume is about 27 million times the volume of our sun. If it could be transferred to the center of our solar system, it would engulf the sun, Mercury, Venus, and the earth in its titanic bulk and would reach out almost to the orbit of Mars. Betelgeuse is probably at least 160 light-years from the earth.

Light from the Stars and Planets.—Although the stars are all distant suns and shine by their own light, the sun gives us more light and heat in a second of time than do all the stars in the course of a half century.

The planets have no light of their own; the light that comes to us from them is a reflection of the light of our sun. If we could stand upon any one of the nearer planets, we should see the earth by reflection of the rays of the sun. It would appear among the stars as a point of steady light. The longest rays of reflected light known to man are those which come to us from the most distant planet, Neptune. When the astronomer turns his telescope on Neptune and its moons, he sees rays of light which have traveled from the sun to Neptune and have been reflected back to earth—a total distance of about five and a half billion miles.

SUMMARY

To the casual observer, the array of stars in the evening sky is bewildering. The ancients grouped these stars into constellations which vaguely resembled animals of ancient heroes. The best known modern groupings are the Big Dipper and the Little Dipper, because they are always in view in the northern heavens. Of all the stars in the

heavens, the North Star alone seems to be almost stationary. All the stars in the northern heavens seem to circle about it, and the stars farther to the south seem to rise in the east and set in the west. All of these apparent movements of the stars are in reality caused by the rotation of the earth on its axis and by its annual revolution around the sun.

While the stars do not seem to change their positions in relation to each other, there are a few steady-shining points of light that are constantly shifting their positions among the stars. These are the planets. Like the earth they revolve in regular orbits about the sun as a center. The four planets farthest from the sun—Jupiter, Saturn, Uranus, and Neptune—are the largest. Of the four closest to the sun—Mars, Earth, Venus, and Mercury—the earth is the largest. Venus and Mars are the only two planets besides the earth on which it seems possible that life could exist.

The sun is more than 100 times greater in diameter and in circumference than the earth. It appears as a tremendous ball of flame, with white-hot gases shooting out for hundreds of thousands of miles. Occasional furious storms appear on its surface as black sun-spots. These seem to have something to do with great electric disturbances on earth. The sun is the source of all the light and heat that make life possible on earth.

The stars are distant suns. Some of them are vastly greater than our sun. Betelgeuse, one of the giants of the heavens, has a diameter almost 300 times that of our sun, while its volume is about 2700 million times the volume of our sun. Even the nearest of the bright stars is so far away that a ray of light from it, traveling at the rate of 186,000 miles a second, requires about four and one-third years to reach us. Because of the great distances that separate us from the stars, we receive less light and heat

from them in a half-century than from the sun in a second of time.

QUESTIONS

What do we mean when we speak of the constellations? How did the names of most of the constellations originate?

Do the stars appear to change their positions in relation to each other? Explain the apparent movements of the stars.

What is meant by the "North Pole of the Heavens"?

How can a planet be distinguished from a star?

How many planets are there? Name them in order from the sun. Which is the largest? What two besides the earth may possibly be inhabited?

How large is the sun as compared with the earth? Describe the surface of the sun.

What is a star? What is meant by a light-year?

Of what importance to us is the light of the sun? Do the planets shine by their own light? Do the stars?

CHAPTER II

THE UNIVERSE IN MOTION

*So rolls the changing year and so we change;
Motion so swift, we know not that we move.*—Mulock.

What are the movements of the heavenly bodies? How do these movements affect us and why do they continue uninterruptedly through the ages?

“Time and tide wait for no man,” says an old proverb. This is another way of saying that the earth and the moon will not halt for anyone. If everything in the universe were standing still and no changes were occurring, there would be no means of measuring time. Time is a measure of movement—of change. Direction and place are determined by the movements of the earth and its relation to the sun. Day and night, the seasons, the year, and even the tides of the ocean, are but the results of tremendous movements in space that occur with unfailing regularity.

I. MOVEMENTS OF HEAVENLY BODIES

Days and Nights on the Planets.—The ancients regarded the earth as the center of the universe, and thought that the sun, moon, and stars revolved around it. To this day we speak of the “rising” and “setting” sun, as if the sun were making the trip around the earth once a day.

In reality, of course, there is no rising nor setting of the sun. The sun in its brilliancy is always shining on the earth and the other planets. As the earth rotates from

west to east, we are turned into and out of the light of the steadily shining sun. It is difficult for us to realize, as we go about our daily tasks, that the rotating earth whirls



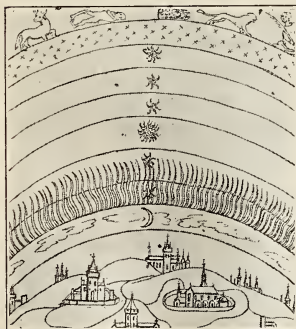
Courtesy of Lowell Observatory.

SERIES OF DRAWINGS OF MARS SHOWING ROTATION OF THE PLANET

The figures indicate degrees of longitude. These observations were made when the upper hemisphere was in its spring season and the lower hemisphere in its autumn season.

us from west to east at the rate of over 17 miles a minute. And so the sun *seems* to journey overhead from east to west.

The period required for a single rotation, through dawn,



MEDIEVAL IDEA OF THE UNIVERSE

From a fourteenth century manuscript. Above the earth are the clouds and the moon; then the rays of the sun; next the various planets; above them the stars; and finally the signs of the zodiac.

midday, fading light, and outer darkness, gives us one of our means of measuring time. The division of this period into twenty-four hours, with subdivisions of sixty minutes of sixty seconds each, dates back thousands of years to the Chaldeans. We use the number 100 as a standard of counting, but the Chaldeans liked to calculate in multiples and fractions of 60, because that number is divisible both by 10 and by 12.

Astronomers have never satisfactorily determined

what the length of day is on Mercury, Venus, Uranus, and Neptune—the two planets closest to the sun and the two most distant. A day on Mars differs little in length from the twenty-four hour day of the earth, but Jupiter and Saturn whirl completely around on their axes once in about every ten hours.

Years on the Planets.—The earth moves in its orbit around the sun with the tremendous average velocity of about *19 miles a second*. It is this revolution around the sun that gives us our measure of time which we call a year. It takes 365 days and a fraction to complete this revolution; and so we reckon 365 days to be a year, and add a day practically every fourth year to account for the fractions.

The paths of the planets around the sun vary greatly in length. Mercury completes its comparatively short trip around the sun in about 88 days—which may be called Mercury's year. Venus requires less than two-thirds of the earth's time for its annual trip, while Mars, the next planet beyond us, has a year almost twice as long as ours. Neptune traveling the "outer rim" of our solar system, requires 164 of our years to traverse its vast orbit once.

Astronomers speak of the "mean," or average, distance of the planets from the sun. This is because a planet in its journey around the sun does not move in a circle, but in an *ellipse*.

Demonstration.—Stick two pins into a piece of cardboard, a short distance apart. Place over the two pins a loop of string, and with the point of a pencil draw the loop taut as in Figure 3. If the loop is kept taut as the pencil point moves around the two pins, the resulting curve will be an ellipse. The points where the pins pierce the cardboard are called the *foci*.

This illustrates very roughly the shape of a planet's orbit. Any drawing we should make with the foci far enough apart to make clear to the eye that the figure is an ellipse and not a circle would not rep-

resent accurately the outline of a planet's orbit. Figure 102 represents more nearly the shape of the earth's orbit, but even in this drawing the foci are proportionately much too far apart.

Now the sun is at one of the foci of the ellipse in which the earth moves, and so the distance between the sun and the earth varies during the year.

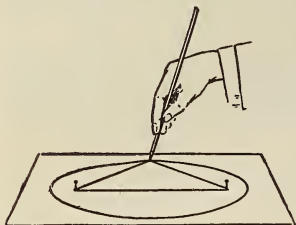


FIGURE 3.—DRAWING AN ELLIPSE

Why the Planets Are Not Perfect Spheres.—Experiment 1.—Attach a centrifugal hoop to a rotator apparatus and revolve. What difference do you notice in the shape of the hoop as

it begins to rotate rapidly? (Figure 4.)

Rotate the apparatus at different rates of speed. What difference does increased speed seem to make in the shape of the hoop?

As a result of the spinning on their axes, the planets are not perfect spheres, but oblate spheroids; that is, spheres that are somewhat flattened at two opposite points. An ordinary orange has this shape. Jupiter and Saturn are so flattened at their poles and so bulged at their equators that they appear plainly through the telescope as oblate spheroids—even to the eye of the ordinary observer. Their exaggerated orange shape is probably owing to the fact that their surfaces are not solid and their speed on their axes is extraordinarily great.

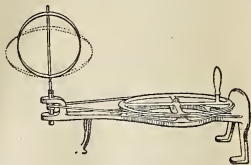


FIGURE 4

Men who have in different ways made careful measurements of the shape of the earth tell us that its shape is very much nearer that of a perfect sphere than that of

an orange. Its polar diameter is only 27 miles shorter than its equatorial diameter; and so when we consider that each of its diameters is nearly 8000 miles, a shortening of only 27 miles in one of these would not change



TWO VIEWS OF JUPITER AND ITS MOONS

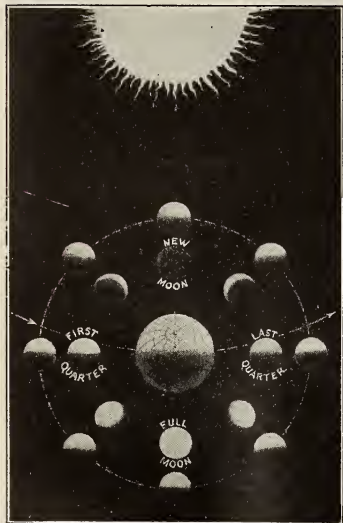
Showing changes that occurred in the positions in a period of 8 days.

the spherical shape enough to be noticed except by the most careful measurements.

“Grandchildren of the Sun.”—All the planets, except Mercury and Venus, the two closest to the sun, are accompanied by smaller bodies, which are called *satellites* or *moons*. These moons revolve about their planets just as the planets revolve around the sun. They have no

light of their own, but shine, as do the planets themselves, by the reflected light of the sun.

These moons differ greatly in size. Mars has two little moons, one of which is only ten miles in diameter and makes three trips a day in its orbit about the parent planet. Four of the ten moons of Jupiter are larger than our own moon.



PHASES OF THE MOON

A drawing that shows roughly the varying positions of the sun, moon, and earth.

light at one end of the room. Obtain a bright steel ball, a freshly varnished croquet ball, a clean baseball, or any other bright spherical object that is easy to handle.

With your thumb and forefinger, hold the ball at arm's length between your eyes and the light. Keep your arm rigidly in position and slowly wheel on your heel in a circle to the left.

When you hold the ball between your eyes and the light, the side that is illuminated is turned away from you, and the side toward you is in the shadow. As you slowly wheel in a circle, what is the

Phases of Our Moon.—Our moon has a diameter of about 2000 miles, as has been said, but it contains only about one-eightieth as much matter as does the earth. It revolves around the earth in a little less than twenty-eight days. Primitive peoples measured time by "moons." This is the origin of the word *month*.

Experiment 2.—Darken a room. Place a strong

light at one end of the room. Obtain a bright steel ball, a freshly varnished croquet ball, a clean baseball, or any other bright spherical object that is easy to handle.

shape of the very first portion of the surface that you see directly lighted? When you have turned a quarter of the way around, how much of the lighted surface do you see? When you have made half the circuit? When you have made three-quarters of the circuit? When the ball is approaching its original position between you and the sun, what is the shape of the directly lighted surface?

When the moon is in that part of its orbit nearest to the sun, it is almost between the sun and the earth, and the illuminated side is turned away from us. As it moves eastward in its orbit, it appears on the western horizon as a thin crescent of light. This is called the "new moon." If it is observed every night at the same hour it will appear farther east. This is because of its eastward movement in its orbit. The farther east it moves, the more of its lighted surface we see. When it has finished a quarter of the round of its orbit, we see half its lighted surface. This is called the "first quarter." When it has completed half its journey around the earth and is on the opposite side of the earth from the sun, we see the entire half of the moon that is illuminated. This is the "full moon." These changes of appearance are called the moon's *phases*. As the moon traverses the other half of its orbit back to a position between us and the sun, the phases described are again seen, but in reverse order.



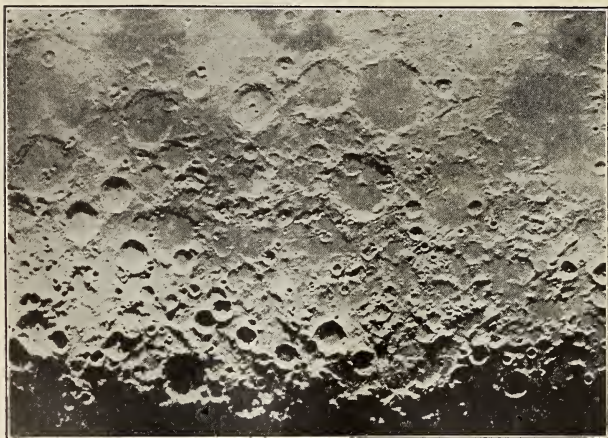
PHASES OF THE MOON

Drawings showing the varying appearance of the moon as it travels in its orbit around the earth.

The position of the crescent moon never has anything to do with the weather. The points, or cusps, of the crescent moon always extend away from the direction of the sun. The diagram on page 30 shows why the cusps of the "new moon" point eastward, and the cusps of the "dying moon" point westward.

If you will look at the new moon on a clear night when

it is in its thin crescent stage, you will probably see the dim outline of the entire face of the moon, "the old moon in the new moon's arms." Three hundred years ago, Galileo concluded correctly that this dim outline of the dark side of the moon was made visible by the reflection of the sun's light from the surface of the earth; for the larger earth naturally reflects more light to the moon than the moon reflects to the earth.



SURFACE OF THE MOON

Showing the great crater-like depressions.

Although we see the moon as a very bright object for a part of every month, yet astronomers tell us that we receive more light and heat from the sun in a quarter of a minute than is reflected from the moon in a whole year.

The moon turns only once on its axis during a revolution around the earth, and so it always keeps the same side toward us. Since the period of revolution is just a little

short of twenty-eight days, the moon's periods of daylight and darkness are about 14 of our days long.

Surface of Our Moon.—There is no air nor water on the surface of the moon, and consequently there can be no life as we know it. Since the moon has not the leveling influence of wind and rain and freezing water, its surface is very jagged, and some of its mountains rise to greater heights than our tallest peaks. The surface of the moon is pitted with thousands of great craterlike depressions, some of which are more than a hundred miles in diameter. The origin of these craters, astronomers can only guess at. What we see as the "man in the moon" is outlined by shadows which are cast by tall mountains and crags.

Eclipses of the Sun and Moon.—It must sometimes happen that the moon comes *directly* between the sun and the earth. The moon is so much smaller than the earth, however, that it does not cut off the face of the sun from the entire surface of the earth, but merely from a comparatively small spot. As the earth rotates to the

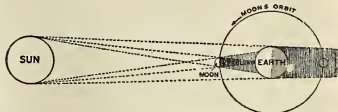


FIGURE 5.—ILLUSTRATING THE CAUSES OF THE ECLIPSES OF THE SUN AND MOON

east, this shadow seems to move westward, making a dark path while the eclipse lasts. This path from which the rays of the sun are entirely cut off is the path of *total eclipse of the sun*. For hundreds of miles on each side of this path, part of the rays of the sun are cut off from view and so a *partial eclipse* is visible. (Figure 5.)

It is during a total eclipse of the sun that pictures are taken of eruptions of incandescent gases on the sun's surface. These form a *corona*, or *crown* of light on the surface of the sun, that surrounds the black outline of the moon.

It must also happen that the earth comes at times between the moon and the face of the sun. If the earth's path lies directly between the two bodies, its shadow wholly obscures the face of the moon for a short time. This is called a *total eclipse of the moon*. (Figure 5.)

Meteors and Comets.—Planets, moons, and asteroids are not all that go to make up the family of the sun. There are countless billions of very small bodies in what we are used to think of as “empty space.” “Pocket planets” the great scientist Humboldt used to call them. Swarms of these meteors travel around the sun faster than the earth, in orbits so great that some of them probably extend far beyond the planet Neptune.



TOTAL ECLIPSE OF THE SUN

From a photograph taken June 8, 1918.

Millions of *meteors* enter our atmosphere every day, traveling at a possible average rate of 30 miles a sec-

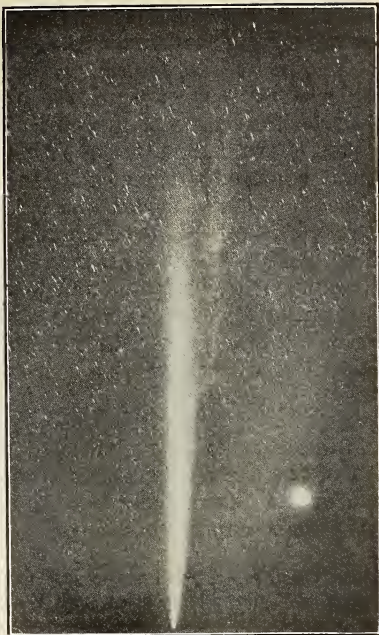
ond. This speed is so very great that the friction of the air causes the meteor to flash into light as a “shooting-star, and to be consumed to ashes before it comes within twenty or thirty miles of the earth. Only a very few of them are large enough to flash into view. Occasionally remnants of larger meteors reach the surface of the earth. These chunks of metal and stone, called *meteorites*, are always objects of great curiosity. A meteorite weighing more than 1600 pounds was found in Texas and is now in the Peabody Museum of Yale University. But the most extraordinary specimen weighs 100 tons and is now in

possession of the American Museum of Natural History.

Sometimes *comets* appear in the sky and excite the greatest wonder. In a comet's head there is usually a bright spot, or *nucleus*. This bright nucleus may be anywhere from 100 to 5000 miles in diameter, and the entire head may range in size from a few thousands to hundreds of thousands of miles in diameter. This head shades gradually into a less luminous tail that streams across the sky for millions of miles and always points away from the sun.

Some of the com-

ets travel in great orbits around the sun and appear at regular intervals. These may be considered a part of the solar system. Others have appeared once and then have disappeared, apparently never to return. Halley's comet is probably the best known of all the comets. It was named after the English astronomer Halley because, by



HALLEY'S COMET

Photographed at the Lowell Observatory May 13, 1910, while the comet was in the morning sky. The large white object to the right of the comet is the planet Venus. The stars appear elongated because the telescope was made to follow the comet while the picture was being taken.

mathematical calculations, he traced its history almost to the beginning of the Christian era, and prophesied correctly the year of its next return. Its last appearance was in 1910. It will not return again until 1986.

Astronomers are not agreed as to what comets are; that is, as to the matter of which they are composed. But it is generally agreed that the stuff of which they consist is so finely divided that a collision even with the nucleus of one of them would probably not result seriously for the earth. It is thought that they may be made up of meteors flying in swarms, and that the meteors which enter our atmosphere every day may be the remnants of comets. Twice in the nineteenth century the earth passed through the tail of a comet without any disturbance to us whatever.

Movements of the Sun and Stars.—So much is said of the sun as the center around which the planets revolve that we are likely to think of it as a giant sphere that is fixed somewhere in space.

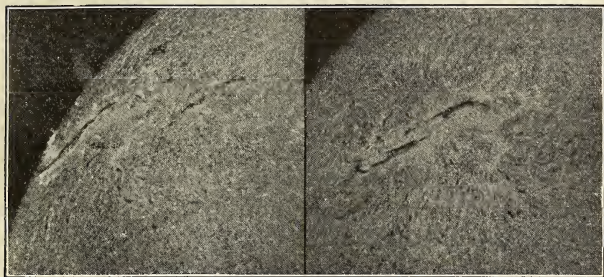
Experiment 3.—If you had the good fortune to find a sun-spot, as directed in the assignment on page 17, look again and see if it is now in a different position on the face of the sun. Watch it every day for a week or so and see whether it changes positions.

Astronomers have proved that the sun turns on its axis. By watching the course of sun-spots, they have determined the length of time required for a single rotation. It takes a sun-spot about 14 days to travel across the face of the sun. It disappears for the same length of time and then re-appears on the opposite rim, showing that the period of rotation of the sun is about 28 days.

Not only is the sun rotating on its axis; it is also rushing through space with tremendous speed, carrying the entire solar system with it. Astronomers agree that the general

direction in which the sun is speeding with his family in orderly array is toward the bright star Vega (page 9).

We are accustomed to call the stars "fixed" because in the lifetime of a man no change could be detected in the positions of any of the stars except by the use of the most highly perfected measuring instruments of astronomers. The immeasurable distances to most of the stars make it impossible to detect any motion at all, even over great



POSITIONS OF SUN SPOTS

Showing revolution of the sun. The first picture was taken on August 3; the second, August 5, 1915.

periods of time. Yet astronomers, reasoning from what we know of the solar system and of the nearer stars, are sure that there is no such thing as a fixed heavenly body. It has been proved that certain of the nearer stars are traveling at rates of motion varying from 10 to 200 miles a second.

Very few stars appear to be traveling in directions across our line of vision. Even those few would require hundreds or even thousands of years to change their positions in the sky by a space as great to the eye as the apparent width of the face of the full moon. No wonder in a universe on so vast a scale, the stars seem fixed, and the shapes of star-groups remain so nearly what they

were when the ancients named the constellations hundreds and hundreds of years ago.

II. WHY THE SOLAR FAMILY KEEPS TOGETHER

Why do the planets keep going in their regular orbits around the sun, and why do the moons maintain their regular courses around the planets? More than two hundred and fifty years ago, the great scientist Sir Isaac Newton pondered these questions as he sat in his garden. A falling apple attracted his attention. Why did the apple fall? Apparently because the earth pulled the apple to its surface. But if the earth pulls to its surface all smaller things that are nearby, is it not reasonable to suppose that it also exerts a pull on the moon? Is it not probable that the sun exerts the same kind of pull on the earth and the other planets?

Gravitation.—It was sixteen years after the incident of the apple before Newton was ready to announce his theory and to offer mathematical proof for his famous *Law of Gravitation*. His theory was that all bodies of matter have an attraction for each other. The sun attracts the planets and the planets attract the sun. The planets attract their moons and the moons exert attraction upon their planets. This force of attraction is always acting upon all bodies and their conduct is constantly affected by it.

When this attraction is considered in relation to the earth and bodies near its surface, the term *gravity* is used. We are constantly measuring the pull of gravity and calling it *weight*. It is the force that causes us to lie down when we wish to sleep comfortably, and that makes all unsupported bodies fall to the earth.

When considered as a force acting between heavenly bodies, it is called *gravitation*. Newton discovered that the force of attraction between two bodies varies as the

masses of the two bodies; that is, the more matter two bodies contain, the more they attract each other. But this attraction becomes less as the distance between the two bodies increases. The lessening of the force of gravitation owing to the increase of distance between them is proportional, not to the distance but to the square of the distance. This means that if the distance between two bodies is doubled, the attraction between them is only one-fourth as great. Moved three times as far apart, the bodies have only one-ninth the attraction for each other; and so on.

The Meaning of "Inertia."—Experiment 4.—Place a coin on a smooth card extending slightly beyond the edge of a table. (Figure 6.) Suddenly snap the card horizontally. Does the coin move?

When the card was snapped from under the coin, the coin moved very slightly, if at all. The force of the finger was applied only to the card, and the card was so smooth that it did not convey any appreciable motion to the coin. If the coin had been glued to the card, both coin and card would have moved.



FIGURE 6

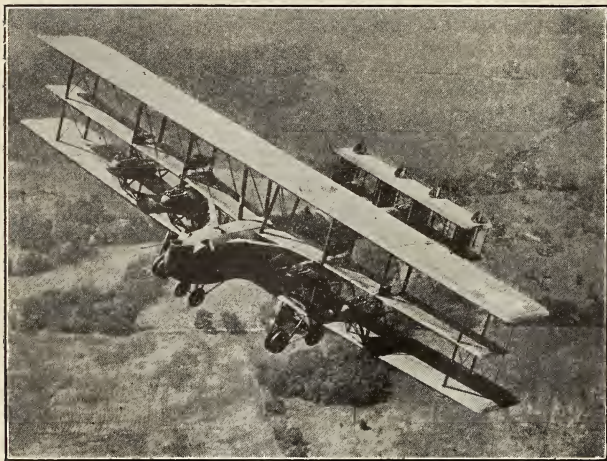
This illustrates the truth that a body at rest remains at rest unless acted upon by some force.

Experiment 5.—Roll a marble or a ball along a smooth floor, and watch its course. Unless it strikes some fixed object, such as a chair or a desk, or some unevenness in the floor, it tends to go in a straight line. But gravity, pulling it against the floor, causes friction, which eventually stops the marble.

It is easily imaginable that if there were no fixed objects nor any force to stop the marble, it would continue in a straight line at its initial speed forever. A bullet fired from a gun would continue in a straight line until it hit some unyielding object if it were not continually

being pulled to the earth by gravity. Newton concluded that a body set in motion continues to move in a straight line at the same speed unless acted upon by an outside force.

Thus a *force must be exerted to move a body* which is at rest. If a body is in motion, a force is needed to *stop it*,



INERTIA MAKES POSSIBLE THE FLIGHT OF HEAVIER-THAN-AIR MACHINES

This dreadnaught of the air was designed for the United States Government by an Englishman, Walter Barling. It weighs 40,000 pounds and its tanks hold 2120 gallons of fuel.

to turn it from its straight course, or even *to alter its speed*. Sir Isaac Newton first stated these facts and so they are sometimes called Newton's First Law. This property of all matter is called *inertia*.

When a passenger is standing in the aisle of a car that starts to move suddenly, he is jostled toward the rear of the car. He is in the position of the coin on the card. The force is applied to the car to start it, and the car

tends to leave him in space just where he was standing. When the car stops suddenly, the standing passenger is pitched forward. This is because force is applied to the car to stop it, while the passenger tends to continue his motion forward. When a car swings suddenly around a sharp curve, the standing passenger feels himself thrown toward the outside of the curve. In this case, force has been applied to the car to change its direction, but the passenger tends to move straight on in the original line.

It is the inertia of water, its tendency to remain in its original position, which enables the rapidly revolving propeller to move a big ship. The resistance which the particles of air offer to being thrown into motion does not seem great when we move slowly through it, as in walking. But when the propeller is pulling an airplane along through the air at great speed, the inertia of the air makes it possible to keep the heavier-than-air machine from falling to the ground.

Why the Planets Move in Curved Paths.—Experiment 6.—

Revolve around the hand a small weight attached to a rubber band. Suddenly let go the band. Does the weight keep on moving in the circular path in which it was revolving? (Figure 7.)



FIGURE 7

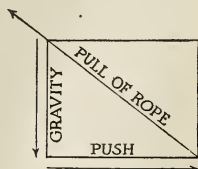
The throw of the hand tended to send the weight off in a straight line. But the pull of the hand exerted through the rubber band tended to pull the weight back. The result was that the weight neither went off in a straight line nor came in toward the hand, but traveled in a curved path. If two forces act upon a body free to move, each will influence the direction of its motion. The body will go in the direction of neither force but in a path between.

So it is with the movement of the earth itself and of all

the heavenly bodies. What primal energy set the heavenly bodies in motion, only the Divine Mind knows. But once set in motion, these bodies must keep on forever unless some force stops them. The tendency of the earth and all the planets is to move away in a straight line. But they can not get away from the attraction of the giant



sun. The sun attracts the planets and the planets attract the sun; but the mass of the sun is so many hundred times greater than that of all the planets and their moons combined that it holds all these in their



THREE FORCES IN PLAY

The diagram to the right shows in what direction each of the three forces is acting.

The circular path of the swing, forward and backward, is the result of the action of three forces.

paths and keeps them from flying away into space, as the rubber band kept the weight from flying away from the hand. The earth is eighty times greater in mass than the moon, and so the moon is held to its path around the earth, and keeps it company in its journey around the sun.

When we let go the band, the weight started off in a straight line (Figure 7). If it were not for gravity, all things at the surface of the earth, having the motion of the revolving sphere, would tend to move away in a

straight line as the earth turned from under them. What happens when there is not sufficient restraining force is seen when the mud flies from the tires of a rapidly moving vehicle. So the earth would leave its orbit and fly straight off into space if it were not for the restraining pull of gravitation.

Mapping the Courses of the Planets.—So accurately do mathematicians know the masses of the sun and of the other members of the solar system, and the distances that lie between them, that they can calculate the exact effect of the gravitational pull of one on all others or of all on one. Astronomers can tell just where in their orbits the earth or any of the planets will be at any future time, or were at any past time. The exact date of any eclipse in the future or in the past can be determined, and even the path of the moon's shadow across the earth. Disputed dates of events in ancient history have been determined to the exact hour in this way.

A little over 140 years ago when Uranus was discovered it was thought to be the farthest planet in the solar system. Astronomers mapped its orbit around the sun and predicted the positions at which it would be found at future dates. Within twenty years the movement of this planet was found to be different from what astronomers had calculated for it. Ten years later it was still farther off schedule.

Finally two mathematicians, one in England, and the other in France, working separately, each without knowledge of the other, concluded that this error in calculating the positions of Uranus must be owing to the pull of a more distant planet, as yet undiscovered. Each one calculated what must be the exact position of this new planet. When on the night of September 23, 1846, a telescope was directed to this point in the heavens, a half hour's

search revealed the planet which now bears the name of Neptune.

Gravitation, the Cause of Our Ocean Tides.—Probably the first thing that impresses us on visiting the sea-shore

is the regular rising and falling of the water each day. These movements of the water are called *tides*. If we observe the tides for a few days we find that there are two high and two low tides each day. As the tidal swell comes in from the open ocean it

FIGURE 8.—DIAGRAM SHOWING RELATIVE POSITIONS OF THE SUN, EARTH, AND MOON DURING SPRING TIDE

is called *flood tide*; and as it runs out or falls, *ebb tide*. When the tides change from flood to ebb or from ebb to flood, there is a brief period of “slack water.”

The tidal undulations have been proved by astronomers to be caused by the rotation of the earth and the gravitational attraction of the moon upon its water envelope. If we observe closely, we shall see that the corresponding tides are nearly an hour later each day than they were the day before, and that

the time required for the completion of two high and two low tides is nearly 25 hours. If the moon were not mov-

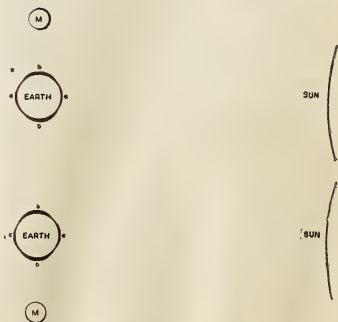
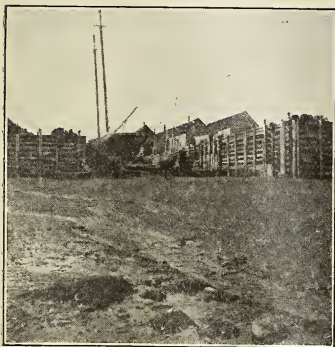


FIGURE 9.—DIAGRAM SHOWING RELATIVE POSITIONS OF THE SUN, EARTH, AND MOON DURING NEAP TIDE

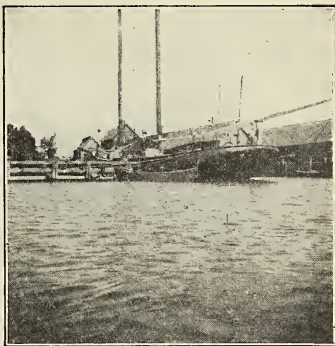
ing in an orbit around the earth, the time for the completion of two high tides and two low tides would be exactly 24 hours. But the eastward movement of the moon in its orbit accounts for the daily difference of an hour.

It is easy to understand why the moon's attraction causes a heaping up of the waters, or a tide, on the side of the earth that is toward the moon. But it seems odd at first to think that there should be a corresponding tide

on the opposite side of the earth. The reason for this is



LOW TIDE IN NOVA SCOTIA



HIGH TIDE IN NOVA SCOTIA

that the gravitational pull of the moon is weaker on the far side than on all the rest of the earth. Thus the moon tends to pull the whole earth away from the water envelope on the other side and to leave the water heaped up by inertia.

It has also been found that the position of the sun as well as that of the moon, affects the height

of the tide. But the moon is much more effective because it is nearer. Continued observation will show, as Julius

Caesar stated many centuries ago, that there is apparently a relation between the phases of the moon and the height of the tides. The greatest rise and fall of the water will be found to occur about the time of the full and of the new moon. This is called *spring tide*. (Figure 8.) Then the earth, moon, and sun lie in nearly the same line, and the sun and moon are acting together. When the sun and moon act at right angles upon the earth, the tidal range is least and this is called *neap tide*. (Figure 9.)

III. DETERMINING LOCATION AND MEASURING TIME

Direction.—When we say *down* we mean toward the center of the earth and when we say *up* we mean the opposite direction. These are the only two directions we could be easily sure of, if it were not for the rotation of the earth. A line running over the surface of the earth directly from the north to the south pole extends *north* and *south*. A line which runs over the surface of the earth at right angles to a north and south line is said to run *east* and *west*; east, as is well known, being indicated by

the rising sun, and west by the setting sun. Thus, the points of the compass, as well as day and night, are determined for us by the earth's rotation.

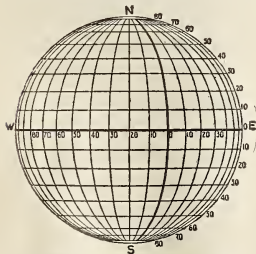


FIGURE 10. MERIDIANS AND PARALLELS OF LATITUDE

Location.—For purposes of measurement, circles of any size are divided into 360 equal parts, called *degrees*. This dates back, as does the measurement of time, to the Chaldeans. Thus

the equatorial circle of the earth may be divided into 360 equal parts. Through each of these points of division imagine a semicircle drawn from pole to pole. These 360 semicircles are called *meridians*.

A certain one of these meridians, usually the one passing through Greenwich, England, is called the *prime meridian*. East and west of this, the meridians are numbered from 1 to 180. The meridian directly on the opposite side of the earth from the prime meridian is the 180th meridian east or the 180th meridian west. The degrees thus numbered east and west are called *degrees of longitude*.

Each meridian, being a semicircle, is divided into 180 parts or degrees. Through each of the 180 points of division a

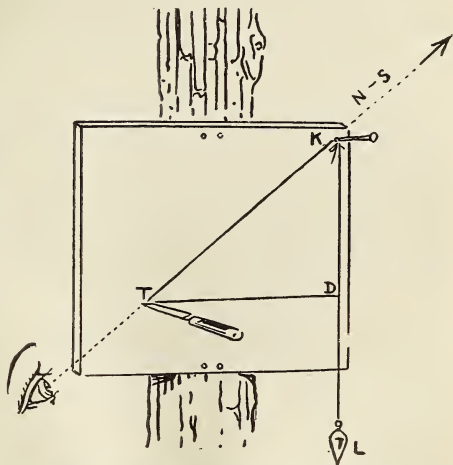


FIGURE 11. DIAGRAM SHOWING BOY SCOUT METHOD OF DETERMINING LATITUDE

circle parallel to the equator is passed; and each of these circles marks a degree of latitude—90 degrees north, and 90 degrees south. These circles gradually decrease in size from about 25,000 miles at the equator to points at the poles. They are called parallels of latitude and are numbered from 0 at the equator to 90 at the poles.

Thus we have a skeleton outline by means of which we are easily able to locate the position of any place upon the earth. To secure greater accuracy than could be obtained by giving merely the degrees of latitude and longitude,

each degree is sub-divided into 60 equal parts called *minutes*; and each minute can be divided into 60 equal parts called *seconds*.

Voluntary Project.—Determine your latitude by means of the North Star. The official Handbook of the Boy Scouts of America gives full directions for doing this. Report the method and the results to the class. Explain to the class by means of Figure 11.

The Measurement of Time.—The rotation of the earth gives us also our means of measuring time.

Although the exact determination of time is a difficult task and requires great skill and very accurate instruments, yet it is not very hard to determine quite satisfactorily the length of a solar day. Before there were any clocks, people told the time of day by *sundial*, which consisted of a vertical "pointer" the shadow of which fell upon a horizontal plane.

Experiment 7.—On a day when there appear to be indications of settled weather, place a table covered with blank paper in an open space where the sun can shine upon it. Be sure that the top of the table is level and then fix it firmly so that it cannot be moved.

Fix vertically upon the south edge of the table a knitting needle.

When the sun is approaching the highest point in the heavens at midday, be on hand to make your observations. As often as the shadow changes slightly, make a dot at the tip of the shadow and keep a record of the time of each dot.

The shadows will keep getting shorter and shorter until the sun reaches its height and then they will begin to lengthen again.

The direction of the shortest shadow is a north and south line, since the sun is at its highest point and is therefore half-way between the eastern and western horizons. This shortest shadow marks your *local noon of a solar day*. Before the coming of railroads and telegraphs, each community measured its own time in this way, by the "passing of the sun." From local noon, or the time the sun cast the shortest shadow on one day,

until local noon, or the time of the shortest shadow, the next day, was regarded as a day's time or a *solar day*.

Standard Time.—When railways extending east and west became numerous in the United States and there were many through trains and numerous passengers, it became very inconvenient to use local time, since no two places had the same time. Each railway therefore adopted



MAP SHOWING STANDARD TIME BELTS OF THE UNITED STATES

The boundary lines of this map are based on the railway division points of time change. Only cities and towns at such points are indicated. See page 50.

a time of its own, and when several railways entered the same city, these different times became very confusing. Therefore in 1883 the American Railway Association persuaded the Government to adopt a uniform system of time-keeping for the entire country.

The result was Standard Time, and the plan was simple. Since the earth rotates on its axis (the full 360 degrees of its circumference) in 24 hours, it turns in one hour $\frac{1}{24}$ of its circumference, or 15 degrees. Places on the earth's

surface that are 15 degrees apart in an easterly-westerly line may, therefore, be regarded as an hour apart in time.

The United States Government adopted four meridians at intervals of 15 degrees across the country as standard time meridians. The meridians adopted were 75° for Eastern, 90° for Central, 105° for Mountain, and 120° for Pacific Time. For $7\frac{1}{2}$ degrees on each side of a standard meridian, the time used is the local time of the standard meridian. The divisions thus formed are called time belts and are an hour apart by Standard Time. When a person crosses westward from one belt to another, he finds that his watch must be set a full hour back. Going eastward, he must set his watch forward an hour when he crosses from one belt to another.

In actual practice, the boundary lines are not exactly $7\frac{1}{2}$ degrees on either side of the standard meridians. It has been found more convenient to run boundary lines through the nearest railway division points of importance.

Your watch is set to Standard Time and may be as much as thirty minutes fast or slow, as measured by your local solar time.

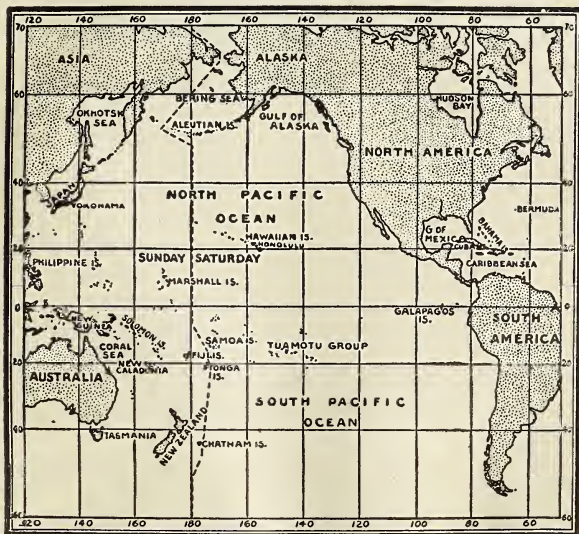
Notice the time of the dot marking the shortest shadow in Experiment 7. If you are some distance east of your standard meridian (see the map), you found that your minute-hand had not reached twelve o'clock when you marked the dot showing local solar noon. Why? If you live west of your standard meridian, you found that your minute-hand had passed twelve. Why?

If the earth turns 15 degrees of its circumference in an hour, it turns one degree in four minutes. By finding the difference between noon as shown by your watch and noon of your local solar day, can you tell roughly how many degrees you are east or west of your standard time meridian?

The civil or conventional day begins at midnight, not noon. The determination of the exact time is very important; for the United States it is done at the Naval

Observatories at Washington and at Mare Island, San Francisco, and telegraphed each day to different parts of the country.

This system of standardizing time has been extended to all the United States possessions, and is coming into general use over a large part of the world. Argentina has recently established a system of standard time.



MAP SHOWING INTERNATIONAL DATE LINE (Dotted Line)

International Date Line.—If a person could start at noon and travel around the earth from east to west as fast as the earth rotates, the sun would be overhead all the time and no solar day would pass for the traveler, even though twenty-four hours would be required for the journey. But when he reached home he would find that

a calendar day had passed. This shows that daylight never really begins nor ends, and so it is necessary to have some generally accepted north and south line on the earth's circumference from which to reckon the beginning and the ending of a day. The internationally accepted line which

separates one day from the next is the 180th meridian, which extends through the Pacific Ocean.

Since the meridian of Greenwich is usually regarded as the 0° meridian, let us suppose it is high noon of Sunday at Greenwich. For every 15 degrees west of that point it will be an hour earlier, until at the 180th meridian it will be midnight of Saturday. For



FIGURE 12.—DIAGRAM TO SHOW ARBITRARY CHANGE OF CALENDAR DAY AT ABOUT THE 180TH MERIDIAN

every 15 degrees east of Greenwich it will be an hour later, until at the 180th meridian it will be midnight of Sunday.

Thus, on one side of this line it would be Saturday midnight, and on the other side Sunday midnight. This represents the actual state of affairs. Any one traveling around the earth must drop a day from his calendar if crossing this line toward the west, and repeat a calendar day if crossing the line toward the east. (Figure 12.)

In practice, the International Date Line, where this *arbitrary* change of day occurs, does not quite coincide with the 180th meridian. A glance at the accompanying map (page 51) will show why it is convenient to vary the Date Line from the meridian line.

Every sea captain is provided with one or more accurate clocks called *chronometers*, which are usually set to the time of Greenwich. That is, when these clocks register 12 o'clock noon, the sun is directly over the 0 Meridian at Greenwich. Each ship is also provided with sextants, convenient instruments for determining on a bright day the local solar noon of a ship. How can a sea captain, by comparing the local time of his ship with the time of Greenwich know his longitude east or west of Greenwich?

SUMMARY

Day and night are caused by the rotation of the earth. The length of day on any planet depends on the time required for a single rotation of the planet on its axis. A day on Mars differs little in length from one of our 24-hour days, but Jupiter and Saturn rotate on their axes once in about every ten hours. The periods of rotation of the other four planets are uncertain. The length of a planet's year is determined by the time required for a complete revolution around the sun. Length of years on the planets ranges from 88 of our days for Mercury to 164 of our years for Neptune.

Because of their rapid rotation on their axes, planets are oblate spheroids, not perfect spheres. They travel around the sun in elliptical—not circular—orbits.

Each of the planets, except Mercury and Venus, is accompanied by one or more satellites or moons. All satellites revolve about the planets they accompany; and shine, as do the planets themselves, by reflected light.

Our moon contains only about one-eightieth as much matter as does the earth. It rotates once on its axis and travels once around the earth in a little less than twenty-eight days. It has no air nor water on its surface, and consequently no life as we know it. The surface is jagged, with craterlike depressions and lofty crags and mountains that cast deep shadows visible to our naked eyes. The

moon's revolution around the earth accounts for its changing phases and for eclipses of both the sun and the moon.

Swarms of meteors and many comets form a part of the solar system. Meteors frequently enter our atmosphere and because of the friction of the air flash into light as "shooting-stars." Comets are composed of finely divided stuff. Twice during the nineteenth century, the earth traveled through the tails of comets without any disturbance whatever.

The sun also rotates on its axis and travels through space with its family of planets and their satellites in orderly array. All the stars are moving with tremendous speed, but they are so far away that in a lifetime there are no visible changes in their positions.

The laws of gravitation and inertia explain the movements of heavenly bodies. In accordance with these laws, the movements of planets and their satellites may be foretold with accuracy. Gravitation and inertia also enable us to account for the ocean tides.

Direction and place are determined by the movements of the earth and its relation to the sun. If everything in the universe were standing still and no changes were occurring, there would be no means of measuring time. Time is a measure of the earth's movements on its axis and around its orbit.

To avoid endless confusion that would be caused by each community having its own local time, the United States is divided into belts about 15° wide. Throughout one of these belts, standard time is the same, and each belt differs by one hour from a neighboring belt. The International Date Line (about the 180th meridian) is the line which for convenience marks the beginning and ending of a calendar day.

QUESTIONS

What is the cause of day and night on the planets? What is the approximate length of day on Mars? On Jupiter and Saturn?

What gives us our measure of a year? How long is Mercury's "year"? Neptune's?

Why are the planets not perfect spheres?

What are the causes of our moon's changes of appearance? Does the moon shine by its own light?

What is the appearance of the moon's surface? Why is there no life as we know it on the moon?

What causes an eclipse of the sun? Of the moon?

What is a meteor? A meteorite? A comet?

Are the sun and the stars in motion? If so, why do they not seem to change their positions?

What is gravitation? Inertia?

Why do the planets move in curved paths?

What is the cause of tides?

How do we determine directions?

How is time standardized in the United States?

With what meridian does the International Date Line approximately coincide? Explain why by international agreement an arbitrary change of day occurs at that line.

CHAPTER III

FORMS AND MAKE-UP OF MATTER

*For the world was built in order
And the atoms march in tune.*—Emerson.

In the previous chapters we have dealt with the universe as a whole, most of which is immeasurably beyond the reach of the telescope. In trying to find out what it is all made of, we shall find ourselves in a “universe” of particles so infinitely small that no microscope can possibly reveal them. Yet scientists, by means of delicate apparatus and careful reasoning, are just as sure of the existence of these invisible particles as we are of the existence of the earth and the sun.

I. THE FORMS OF MATTER

The earth and the heavenly bodies are composed of a very great number of different substances. With some of these, such as iron, water, air, etc., we are all familiar. These, as well as all other substances, are called *matter*. In short, as scientists say, anything that occupies space—takes up room—is matter.

Matter is known to us in three forms: solids, liquids, and gases. All substances exist in one or more of these three forms. It is easy to see that solids and liquids fall under the classification of matter, because we can see that they occupy space. But air, which is a gas—or rather, a mix-

ture of gases—cannot be seen and may not seem to need space for itself.

Experiment 8.—Pull out the handle of a compression air-pump or bicycle pump. Close the exit valve of the air-pump, or stop up the exit tube of the bicycle pump. Now try to push in the handle. What keeps it from moving easily?

Try to shove an inverted drinking glass into a pail of water. (Figure 13.) Why does not water fill the glass?

In the experiment with the air-compressor we found that the space occupied by the air could be reduced only to a limited extent. Greater force might have compressed the air into smaller space, but no amount of force could reduce the air to a point where it did not occupy at least some space. When we pump up a bicycle tire, we see again that air demands room for itself. In the experiment with the drinking-glass, we found that the water could not occupy the space already occupied by air.

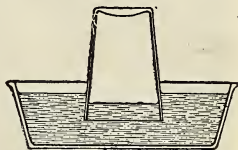
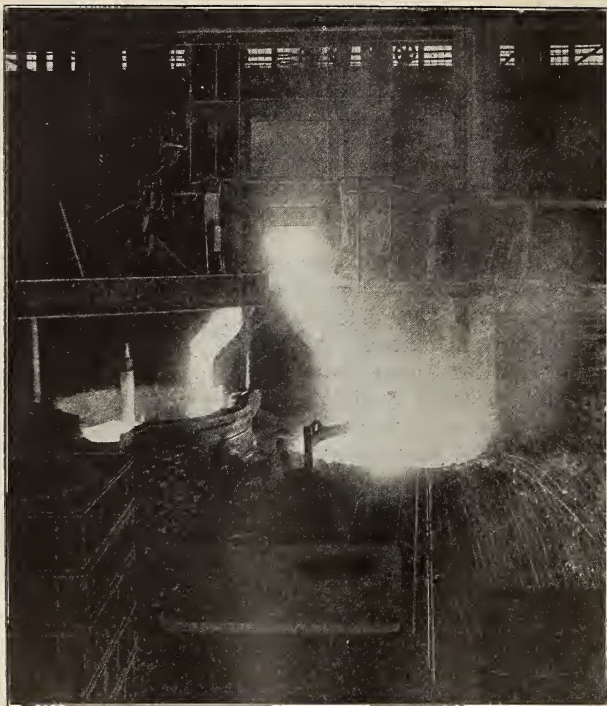


FIGURE 13

Water furnishes the most familiar illustrations of the three forms of matter. The most common form in which water is found is liquid; but as ice it is a solid and as steam it is a gas.

While the effect of heat in changing ice to water and water to steam is familiar to us all, it is not so generally known that the application of heat will change other substances from a solid to a liquid state and from a liquid to a gaseous state. Iron, copper, and zinc, for example, are solids as we ordinarily see them. As they come from the blast furnace, they are liquids. Scientists have proof that in the indescribably hot atmosphere of the sun, these metals exist as gases. When heat is withdrawn, the proc-



Courtesy of American Steel Foundries

MOLTEN STEEL FLOWING FROM A BLAST FURNACE

The liquid steel is here conducted by a duplex spout into two 20-ton ladles, ready for casting in the molds.

esses are reversed, from gas to liquid, and from liquid to solid.

Some substances, such as camphor, pass from a solid state directly to a gaseous state. Ice may do this under certain conditions. Housewives in cold climates know, for example, that clothes will "freeze dry" in zero weather.

II. MAKE-UP OF MATTER

It is the work of chemists to find out of what matter is composed. They tell us that all matter consists of minute particles, called *molecules*.

Size of Molecules.—Experiment 9.—Expose a very small piece of musk, or leave a bottle of ammonia water open in a closed room for fifteen or twenty minutes. Does the odor spread to all parts of the room?

Experiment 10.—Drop the smallest possible bit of indigo into a large vessel of water. Stir. What happens to the entire basin of water?

Although the odor of musk or ammonia can be recognized in every part of the room, apparently nothing has left the substances nor has anything been added to the atmosphere of the room. Molecules are too small to be seen even with the most powerful microscope. A grain of musk (that is, 1-437th of an ounce) will scent a room for ten years and yet not lose in that time one millionth of its substance. A grain of indigo will color a ton of water. Some one has said that if a drop of water could be magnified to the size of the earth, the molecules would probably *appear* no larger than a baseball. If you have ever noticed a soap-bubble carefully, you have seen dark spots in its walls. These are the thinnest parts of the bubble-wall. By means of experiments with light and electricity, scientists have found that these dark patches are from one two-millionth to one four-millionth of an inch thick. Yet even these patches are from 20 to 40 molecules thick.

Motions of Molecules.—As small as molecules are, there is no substance in which these particles are packed together like bricks in a wall. Spaces exist between molecules even in the hardest matter. If you have ever been unfortunate enough to bring a gold ring into contact

with mercury, you have found your ring silvered in color. What happens is that the mercury molecules have forced their way into the spaces between the gold molecules. "Forced" is the right word to use in this connection, because each molecule of every substance is constantly in motion. Every molecule moves with astounding rapidity, bumping and bounding back and forth among neighboring molecules.

When ice is heated, the molecules move more rapidly and strike each other harder. The ice crystals break down. The ice loses its definite shape and melts down into water. When further heat is applied, the motion of the molecules becomes so violent that they fly still farther from each other, causing the water to expand into steam.

Molecules Divided into Atoms.—It has been found possible by chemical and electrical means to divide molecules into smaller particles called *atoms*, and very recently to find out something about the composition of atoms themselves. For example, the smallest particle in which water can exist and still be water is a molecule. By means of an electric current these molecules can be broken up. But when we thus divide the molecules of water we no longer have water; we have two gases, hydrogen and oxygen.

Experiment 11.—(Teacher's Demonstration.)—Procure from the chemical laboratory an electrolysis apparatus, or arrange an apparatus as shown in Figure 14. This consists of a glass dish partly filled

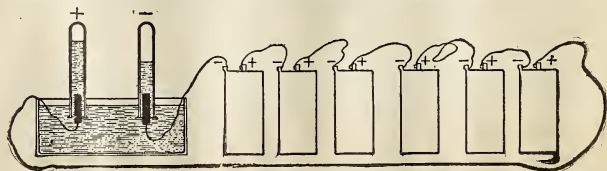


FIGURE 14

with water, into which a little sulphuric acid is *slowly* poured. (The sulphuric acid is needed only to aid in carrying electricity through the water.) Two copper wires, each having a piece of platinum foil attached to one end, are so arranged that the platinum foils extend up vertically in the water.

Fill two test tubes with the water in the dish, and invert them over the platinum foils. To the ends of the copper wires attach a battery of several dry cells, making the connections as indicated in Figure 14.

Bubbles of gas will begin to rise in the test tubes as soon as the battery is connected.

Notice that one of the tubes fills twice as fast as the other. When this tube is full of gas, remove the platinum foil. While the tube is still inverted with its mouth under water, put your thumb firmly over the mouth so as to prevent the escape of gas when you remove the tube from the dish. Now turn the tube right side up, light a match quickly, remove your thumb from the mouth of the tube and hold the lighted match over the open tube. If you have been careful not to let the gas escape before applying the match, there will be a sharp explosion.

Turn the other tube mouth upward and insert a splinter with a glowing spark at its end into the gas. The spark will burst into flame.

The first tube of gas was *hydrogen*, the lightest substance known. You have seen how readily it burns. The second tube of gas was *oxygen*. The greater the supply of oxygen, the more brightly substances burn. We shall learn in a later chapter why this is so.

Chemists have learned that every molecule of water contains two particles of hydrogen and one particle of oxygen. In water this ratio is constant. An atom of hydrogen is hydrogen; an atom of oxygen is oxygen—no other substance. For that reason, hydrogen and oxygen are known as simple substances and are called *elements*. But since the smallest particle of water—a molecule—is composed of hydrogen and oxygen, water is not a simple substance, but a compound of two other substances. Chemists therefore call water a *compound*.

Elements and Compounds.—Every kind of matter known to man is classified as either an element or a compound. So far there have been discovered only eighty-nine elements—eighty-nine substances that cannot be reduced to simpler substances. Among these are such solids as iron, copper, tin, aluminum, lead, zinc, gold, silver, and nickel. Mercury and bromine are two liquid elements, and hydrogen, oxygen, and nitrogen are among the gaseous elements.

Some elements are very common and some are very rare. Oxygen exists in such abundance and forms compounds so readily with other substances that it is said to make up about half of the crust of the earth. About twenty of the eighty-nine elements make up 99 per cent. of the earth's crust. From this it can be understood how difficult it is for chemists to obtain some of the rare elements.

Experiment 12. (A).—Mix a little powdered sulphur with about half as much powdered iron or very fine iron filings.

Examine the mixture with a magnifying glass. Can you easily distinguish between the particles of iron and sulphur? See if you can remove some of the particles of iron with a strong magnet.

Putting these two things together has simply resulted in a *mixture*. Each element is unchanged. If we mix alcohol and water, neither the water nor the alcohol is really changed in nature as the result of putting them together in the same vessel.

If we mix sand and sugar, we can pour water on the mixture and dissolve the sugar. Then we can filter out the sugared water and leave the sand. We may now evaporate the water and find the sugar remaining at the bottom of the dish. Thus *mixtures* make no change in the nature of the substances mixed.

Experiment 12 (B).—Put the mixture of powdered iron and sulphur into a test tube and heat it over a Bunsen burner. (Figure 15.) Keep it there until it glows and becomes a solid mass. Now break the test tube and examine the solid with a magnifying glass.

Can you now distinguish the iron from the sulphur? See if you can separate the iron from the mass by means of a magnet.

This mass is no longer a mixture. The heat caused a combination of the atoms of the two elements into a compound called iron sulphide. This is a different substance from either iron or sulphur.

Most substances are compounds. The number of compounds as compared with the number of elements in nature may be illustrated in this rough way. There are only 26 letters in the English alphabet, but these may be combined in so many different ways that we have thousands of English words. Just so there are to our knowledge only eighty-seven different elements in the world. But these elements unite in so many different ways and in so many different proportions that we have innumerable compounds.

But the comparison of letters and words with elements and compounds must go no farther than to show how many more compounds there are than elements. The eye can pick out all the different letters that compose every word. But when the atoms of different kinds of elements combine into molecules, the resulting compound substance is so different from the elements composing it that there is no apparent relationship.

Water furnishes a good illustration. Oxygen is a gas that must be present wherever there is burning. Hydrogen burns very readily in the presence of oxygen. But water, every molecule of which is made up of atoms of

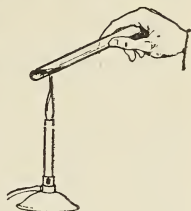


FIGURE 15

these two gases and is the result of the burning of hydrogen in oxygen, is our main dependence for putting out fires.

Matter Can Only Be Changed, Not Destroyed.—Man is unable to comprehend how matter came into being or how any of it can ever be utterly destroyed. We sometimes speak of things being “destroyed” by fire or by explosion or by the action of acids, or by some other means. What we mean in such a case is that the material is rendered unfit for man’s use. It is not actually destroyed; it has simply undergone changes. All the matter that was in a piece of wood that has been burned still exists, but in other forms. Nature may re-employ these very ashes and gases in producing more wood or in growing food for us.

A great many of the changes of matter we understand, and some of these changes we are able in a measure to control. In fact, it is the understanding and control of changes in matter that chemists are constantly seeking.

Experiment 13 (A).—Open a bottle of strong ammonia water and let it stand on the table. Smell the fumes from the bottle but do not put your nose too close to the mouth of the bottle. Dip a glass rod in strong hydrochloric acid. Smell the fumes of the acid.

The fact that you can smell both the ammonia water and the acid shows that changes are taking place in them. They are changing from liquid to gaseous forms. But the nature of the substances is not changed.

When water freezes, it does not become a different substance; it is still water, but water in a solid state. When water is “boiled away” or evaporated by the heat of the sun or changed to steam in the boilers of an engine, it is still water, but water in a gaseous state. When the iron used in Experiment 12 was pulverized it still remained iron. Such changes as these, which do not affect the nature of a substance, are called *physical changes*.

Experiment 13 (B).—Now dip the glass rod in the hydrochloric acid again and hold it an inch or so above the bottle of ammonia water. (Figure 16.) What do you see?

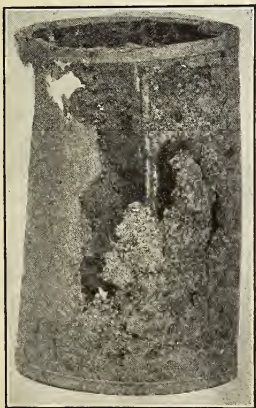
When the molecules of the ammonia and the acid came together they formed a new substance (ammonium chloride or sal ammoniac) that is neither ammonia nor hydrochloric acid. When atoms of two substances unite to form a new molecule, as in this case and in the case of the heated sulphur and iron mixture, a *chemical change* is said to occur. Likewise, when molecules break up into atoms we have a chemical change. Such is the change that occurs when the electrical current breaks the molecules of water into the two kinds of



FIGURE 16

atoms composing them.

One of the most common examples of chemical change is the rusting of iron. When iron is exposed to moisture, two of the gases of the air, carbon dioxide and oxygen, bring about chemical changes that result in combining the iron with the oxygen of the air, forming iron rust. Iron rust is different from either oxygen or iron.



RUSTING OF IRON

Why Changes in Matter Make Life Possible.—Physical and chemical changes are constantly occurring in matter. In

fact we could not live without them. The evaporation of water by the heat of the sun is a physical change.

This water is carried by the winds from lowlands to uplands, to fall again as rain and to flow in streams down to the lowlands. Thus our water-power comes only as a result of physical changes. Fire is caused by chemical change, as we shall learn in the next chapter. Thus we see that physical and chemical changes are at the very base of all industry. Air, moisture, heat, and light combine to produce changes in the substances of the soil and the air that result in plant life and growth. All the growth and activities of our very bodies are the results of physical and chemical changes.

Acids and Bases.—The most important chemical compounds for us to consider are *acids*, *bases*, and *salts*. Acids of various kinds exist in apples, grapes, rhubarb, buttermilk, vinegar, lemons, oranges, and other familiar substances.

A small amount of very dilute hydrochloric acid is formed in the stomach of man and of some other animals and helps in the process of digestion. Hydrochloric acid, sulphuric acid, and nitric acid are much used in the laboratories and in various industries.

Many acids are liquid; and dilute solutions (little acid in much water) of all common acids taste sour. Acids turn blue litmus paper to red. Litmus paper is paper which has been especially prepared by treating it with a vegetable substance called *litmus*, obtained from a low order of plants called *lichens*. Strong acids may cause great injury to cloth, paper, wood, or the flesh of animals.

Bases are in some ways just the opposites of acids. Most bases are in the form of solids, and dilute solutions of almost all the bases taste bitter. Litmus paper that has been turned red by acids will be changed back to blue by a base. Some of the most common bases of the household

are ammonia water, baking soda, limewater, caustic potash (lye), and caustic soda. Certain strong bases are usually called *alkalies*. Caustic potash and caustic soda are two of the commonest and strongest alkalies.

Salts; Neutralization.—Experiment 14.—(Teacher's Demonstration.)—Into a clean test tube containing pure water put a small piece of blue litmus paper. Pour into the test tube a little hydrochloric acid. What happens to the litmus paper? Now add a solution of caustic soda, drop by drop, until the litmus paper takes on a pale bluish red shade. Taste a drop of the solution in the test tube. The test tube will be found to contain water with common salt dissolved in it. By evaporating the water, crystals of salt may be obtained.

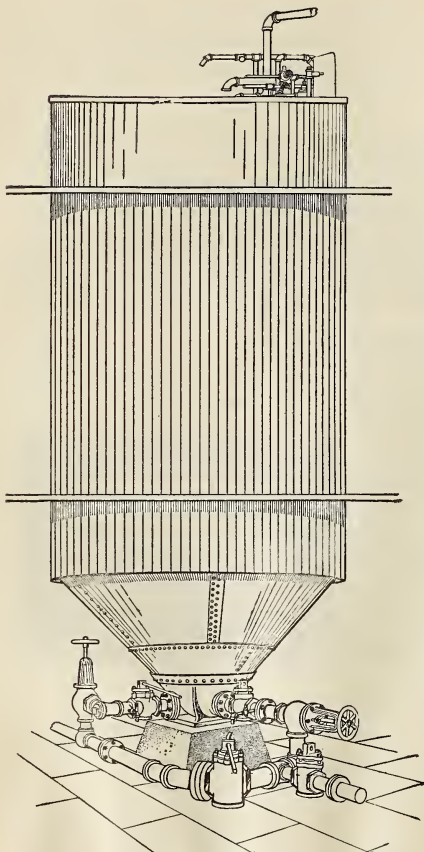
This process of combining an acid and a base in right proportions, by which a substance is produced that is neither an acid nor a base, is called *neutralization*. The result of such a chemical combination is water and a *salt*. There are many different kinds of salts; but the salt with which we are most familiar is sodium chloride, or common table salt, which resulted from the preceding experiment.



ROCK SALT

Strong acids and bases will corrode metals, discolor clothing or even "eat" holes in it, and cause ugly flesh wounds. But neutral substances will do none of these things.

A strong base like lye is just as dangerous to handle as a powerful acid. It is well to bear in mind then that bases and acids counteract or neutralize the destructive effects of each other. If lye is spilled on the hands or clothing, vinegar or lemon juice should immediately be applied to neutralize the base. If acid is spilled,



Courtesy of The Procter and Gamble Company
KETTLE USED IN MANUFACTURE OF SOAP

This kettle is 16 feet in diameter, three stories high, and it holds about 375,000 pounds of soap.

ammonia water is the safest base to counteract it since it will do the least harm, if too much is used.

Every housewife knows that ammonia water may be used in a number of different ways to help remove grease from various kinds of fabrics, and that lye will act upon grease in such a way that water will dissolve it. Lye is therefore used for "cutting" the grease in drain pipes leading from sinks. But since lye and other strong bases which "cut" grease will also ruin most fabrics and will do harm to the skin, a milder cleansing agent must be found for laundry

and personal use. Soap is one of those substances which chemists call *salts*, and is made by mixing or boiling fats with lye. When soap is dissolved, a mild base is released.

The neutralizing of acids by means of some mild base is a part of the daily experience of many people, even though they may not realize what the chemical action is. We put ammonia or damp baking soda on a bee-sting to neutralize the acid that the bee has injected into the flesh. Baking soda is used by housewives to sweeten sour milk. Frugal cooks sprinkle baking soda lightly over rhubarb, gooseberry, or cherry pie in order partly to neutralize the acids and thus to save sugar.

The farmer uses lime to "sweeten" a "sour" or acid soil. Physicians often prescribe limewater or a solution of baking soda to neutralize acidity (sourness) of the stomach. Fruit stains are caused by fruit acids. For that reason, the stains may usually be removed by soaking the linen in a weak solution of ammonia or borax.

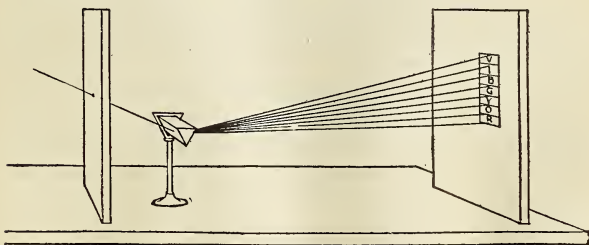


FIGURE 17

How We Know Many Elements in the Make-up of the Sun and Stars.—Experiment 15.—Darken a room except for a small hole in the curtain or shutter, through which a small sunbeam may enter. Note the spot where the beam of light passing through the small hole strikes in the room.

Allow the sunbeam to pass through a glass prism and to fall upon

a white wall or a piece of white paper. (Figure 17.) Has the direction of the sunbeam changed? How has the sunlight been affected? In what order are the colors arranged?

Over nine hundred years ago an Arabian scientist in Spain called attention to the fact that when light passes from a rare substance like air into a denser substance like water or glass the rays of light are bent, or *refracted*, from a straight course.

Newton by many careful experiments proved that white light is made up of different colors; violet, indigo, blue, green, yellow, orange, and red. Each color or shade is bent by the prism at an angle different from that of any other shade, and so the colors are spread out into a band of color which we call the *spectrum*. The violet shades are bent most, as you may readily observe, and the red shades least.

Scientists of the nineteenth century found that by allowing a shaft of light to pass through a very narrow *slit* (instead of through a round hole) in the end of a dark box or tube, and through several successive prisms, the band of color is greatly spread out so that it may be more carefully examined throughout its entire length. This resulted in an instrument called the *spectroscope*.

By means of this instrument, the spectrum, or color-band, of the sun was seen to be crossed by hundreds of dark lines. These remained a mystery to scientists for almost half a century. Two important discoveries revealed their meaning.

It was first discovered that if sodium vapor is made to glow before the slit of a spectroscope, two lines very close together immediately appear at certain places in the yellow portion of the spectrum. Further investigations proved that every element produces lines peculiar to itself, and that these characteristic lines always appear at fixed places. For example, while glowing sodium vapor

always produces two lines in their own places on the yellow band, glowing hydrogen produces one red, one blue, and one violet stripe, always in the same positions on the spectrum. Careful experiments have enabled scientists to map the positions of the lines of every known element.

But the explanation of the dark lines lay in a second discovery. If sodium vapor is made to glow between an artificial light and the slit of the spectroscope, the character of the sodium lines depends on the heat of the artificial light. If the artificial light is cooler than the sodium vapor, the characteristic bright lines of sodium will appear on the spectrum. If the artificial light is hotter than the sodium vapor, dark lines or gaps will appear in exactly the same places on the color-band.

What does this prove about the sun? We have seen that the white-hot sun shoots flaming gases out for hundreds of thousands of miles. Naturally these flaming gases, although they are unimaginably hot, must be cooler than the white-hot core of the sun. If this white-hot core shines through sodium vapor that is cooler, the sun's spectrum will show dark lines or gaps at the places in the yellow band that belong to sodium. Exactly those appear, and so we know that sodium vapor is in the sun.

The *colors* showing in the spectrum of the sun prove nothing. But wherever *dark lines* occupy the positions that belong to an element, we know that element is in the cooler outer layers of gases of the sun. If elements are there, of course they belong to the make-up of the sun. By this method we have learned that in the make-up of the sun and of the stars there are many familiar elements. Iron, copper, zinc, lead, nickel, hydrogen, and carbon are among the familiar substances known to be in the sun.

In the late sixties of the last century, a great English scientist detected in the spectrum of the sun a set of lines

in different places from those occupied by any element known on earth. Because no substance on earth had ever been found that produced these particular lines, he called the unknown element helium, after the Greek word *helios*, meaning sun. Thirty years later, another great scientist discovered in certain minerals a "new" gas that produced the same set of lines. Thus by means of the spectroscope, a substance was identified at a distance of ninety-three millions of miles almost a generation before it was discovered at the surface of the earth.

SUMMARY

Anything that occupies space is matter. Matter is known to us in three forms: solids, liquids, and gases. All substances exist in one of these three forms. All matter consists of particles called molecules, too small to be seen with the most powerful microscope. Molecules are not like bricks in a wall. There are spaces between molecules even in the hardest substances, and all molecules are constantly moving about with astounding rapidity, bumping and bounding back and forth among neighboring molecules.

Molecules may be divided into smaller particles called atoms. If the molecules of a substance can be broken up into two or more different kinds of atoms, the substance is called a compound. If a substance has in its make-up only one kind of atom, it is called an element.

When molecules of substances gain atoms, lose atoms, or exchange atoms with molecules of other substances, a chemical change is said to occur. Any other kind of change in matter is a physical change. Life would not be possible without physical and chemical changes. If when we combine two substances, the molecules remain unchanged, we have a mixture. If a chemical change

occurs when we combine two substances, we have not a mixture but a new compound or compounds. When the atoms of different kinds of elements unite into molecules, the resulting compound is so different from the elements composing it that there is no apparent relationship. Most familiar substances are compounds.

The most important chemical compounds are acids, bases, and salts. Acids exist in many fruits and other familiar substances. Many acids are liquid, and dilute solutions of all common acids taste sour. Acids turn blue litmus paper red. Bases are in some ways just the opposite of acids. Most bases are in the form of solids and dilute solutions of them taste bitter. They turn red litmus paper blue. Strong acids and bases are injurious to flesh or to clothing.

The process of chemically combining an acid and a base is called neutralization. The result of such a combination is water and a salt. A salt has none of the caustic or corroding properties of bases and acids. Using some base to neutralize an acid is a common household experience. Strong bases like lye are used to cut grease from wood or metal. For milder cleansing purposes we use soap, which is a salt that releases a mild base when it is dissolved.

The band of color into which a prism breaks up white light is called the spectrum. The spectroscope is an instrument which spreads out the spectrum and makes it possible to examine this band of color carefully. When matter in a gaseous state is made to glow, each element radiates its own peculiar kind of light. The light from each element produces lines on the spectrum peculiar to itself and these characteristic lines always appear in fixed places on the color band. Thus the spectroscope enables us to identify elements by the kind of light they radiate. By means of the spectroscope, we have learned much concerning the make-up of the sun and of the stars.

QUESTIONS

What is matter?

In what three forms is matter known to us? Give examples.

How can you prove that air is matter or substance?

What happens when clothes freeze dry?

Illustrate by some means the smallness of a molecule.

What relation does there seem to be between the constant motion of molecules and heat?

What is an element? A compound? A mixture?

What is a chemical change? A physical change? Why are changes necessary to life?

What is an acid? A base? Give examples of acids and bases in everyday life.

What is neutralization? Name some ways in which neutralization is of practical service.

How do we know many of the elements in the make-up of the sun and the stars?

CHAPTER IV

NATURE AT WORK

*Weep not that the world changes—did it keep
A changeless, stable state, it were cause indeed to weep.*—Bryant.

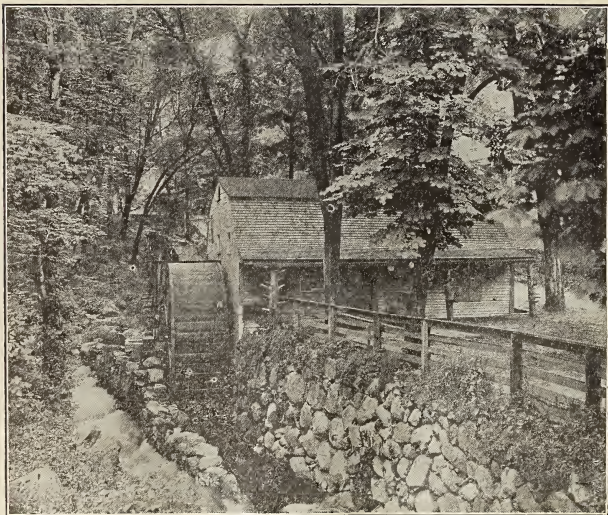
We have learned that matter is never destroyed, though it is always changing. In fact, life and all its activities are made up of changes. What produces them? What is it that “makes things go”?

Everybody has observed many of the effects of heat. It melts ice. It converts water into steam, and thus turns the wheels of industry. Controlled, it warms our homes; uncontrolled, it consumes them. It works in our gardens to produce food and in our kitchens to cook it. Since heat has the capacity to cause change, to overcome resistance, to do work, it is known as a form of *energy*. Whatever has this capacity is a form of energy.

Our Main Source of Energy.—The sun throughout its existence has been sending vast quantities of energy to the earth. This energy has been mostly in the forms of heat and light. At first thought, there may seem to be many other sources of energy, such as water-power, man-power, wood, coal, oil, and electricity. But when these are traced back, their energy is found to have come from one source, the sun. The water which the sun’s energy has evaporated and carried by cloud and shower to the mountain lake has energy by virtue of the position the sun has given it. It is ready to run down the valleys, doing work as it goes. The plants that furnish us bodily

energy and the wood that releases its energy in fire could not grow without the heat and light of the sun.

For untold ages the sun's energy was utilized and stored up by plants. It was preserved in the remains of plants in the form of coal. This coal is now being burned to



UTILIZING ENERGY OF THE FLOWING STREAM

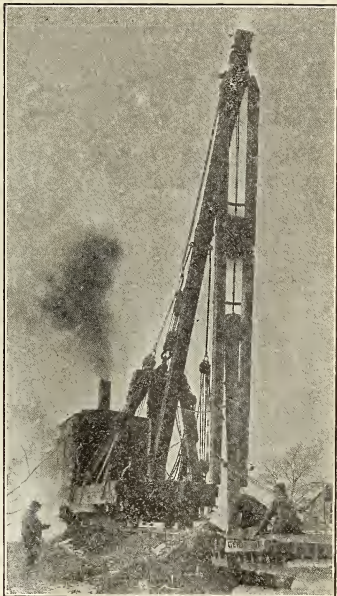
A simple water wheel used for grinding corn.

furnish power to carry on man's industries. Thus nature has run a savings bank. The sun's energy was transformed and stored for ages in the earth's vaults, and now issues from the burning coal to do our bidding. The electric current that moves our cars or lights our homes comes from the dynamo, but the dynamo is driven by the energy that comes from the running stream or the burning fuel. Without the heat of the sun there would be no life on the

earth, no flowing streams, no changing winds, none of the restless energy which makes the world as we know it.

Energy May Be Stored.—Water in the mountain lake, wood, coal, and oil are examples of the storing of energy by nature. Man imitates nature on a smaller scale. In the use of the pile-driver, the energy of the steam-engine is utilized to lift the heavy weight or “ram” against the pull of gravity. When the ram is lifted, it has energy stored up in it, owing to the pull of gravitation between it and the earth. When the ram is released, its stored energy is directed to the driving of the pile. When you wind your watch or a clock, the energy you expend is transmitted to the spring, and the spring is wound into such position that energy is stored in it.

When a gun is loaded with powder it has stored-up energy due to the composition of the powder. The smallest amount of nitroglycerine has stored-up energy on account of the arrangement of its molecules. This stored-up



Courtesy of Illinois Central Railroad
A PILE-DRIVER IN ACTION

The weight or “ram” is lifted to the top of the machine, where it has great potential energy. As it falls, it changes its potential energy into kinetic energy and drives the pile.

energy which a body has through its position or its composition is called *potential* energy.

The moment the body having potential energy begins to do work, its energy is called *kinetic*. The flowing water, the burning wood, coal, or oil, the falling ram of the pile-driver, the slowly unwinding spring of the clock, the exploding powder or nitroglycerine, are all releasing energy, and that energy may be directed to do work for us.

A great many of our everyday conveniences depend on stored-up, or potential energy. Can you think of any examples in your home, in the garage, in schools or in public buildings?

Energy May Be Transformed.—Experiment 16.—Rub a penny briskly on your clothing, on a rug, or on a flat wooden surface. Quickly pick it up and hold it in the palm of your hand. What is the sensation?

Experiment 17.—(Teacher's Demonstration) (A).—Put a few zinc scraps in a test tube and pour a very little hydrochloric acid upon them. Feel the test tube near the zinc.

(B).—Put half an inch of water into another test tube and carefully pour a little strong sulphuric acid *slowly* down the sides of the tube into the water. Feel the tube.

The flowing of water to lower levels and the motion of the falling ram of the pile-driver are manifestations of the energy produced by *gravitation*. The explosion of the gunpowder and of the nitroglycerine are owing to the *chemical energy* released. The ordinary street-car runs by virtue of *electrical energy*. Thus we see that there are other *forms of energy* besides *heat* and *light*.

But one form of energy may readily be transformed into another form. In Experiment 12 *B* heat energy was transformed into chemical energy. In Experiment 17, chemical energy was transformed into heat energy. In the experiment with the penny, chemical energy in the cells of the body was transformed into the mechanical energy of rubbing and this was transformed into heat energy.

In the use of the pile-driver, heat energy is transformed into gravitational energy. For the electric lighting of our homes, the steam engine transforms heat energy into mechanical energy, and this mechanical energy is transformed by the dynamo into electrical energy. The electrical energy is then transformed into light energy. (Figure 18.)

All the work of the world consists of the transformation of energy. We are constantly trying to invent machines

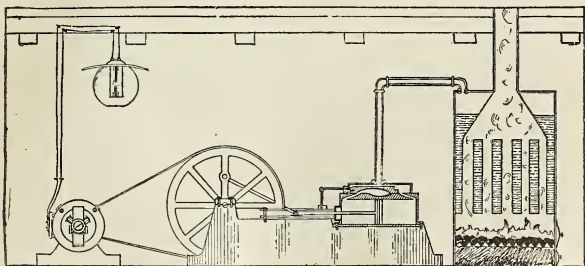


FIGURE 18

that will transform energy economically so that it can be directed to useful ends. The enormous amount of energy in ocean waves, for example, is wasted so far as man's use of it is concerned, because we have found no way of transforming it. Electricity was known as a form of energy for hundreds of years before men were able to transform it effectively and direct it to their own uses.

Mention all the examples you can of the transformation of energy. Do not overlook the simplest examples.

Energy Can Not Be Created nor Destroyed.—Experiment 18.—With a drill bore a hole rapidly in a piece of hard wood. Remove the drill promptly and touch the point of it. What is the sensation?

A portion of the energy you expended went to displace the particles of wood, and a portion of your energy was transformed by friction into heat. The portion of your energy which was transformed into heat is usually referred to as "lost" energy, because it did not help to ac-

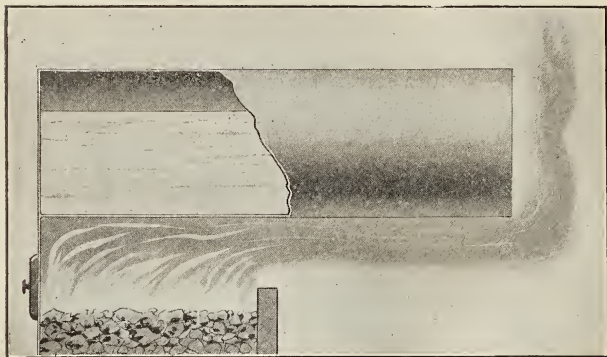


FIGURE 19.—DIAGRAM OF OLD-FASHIONED BOILER
Most of the heat energy went up the flue.

complish the work you set out to do. Whenever man sets out to change one form of energy into another, there is always this "loss of energy."

In a factory, for example, a great deal of heat from the burning fuel goes up the chimney and is lost in other ways. Even that part of the heat which is transformed into mechanical energy cannot all be utilized. Much of it is transformed back into heat by the friction of the moving parts of the machinery.

The machine that makes it possible to use the greatest percentage of transformed energy is the most efficient machine. For example, in the old-fashioned steam-engine, the heat of the fire was applied to a tank-like boiler (Figure 19). A little of the heat was utilized to

change the water into steam, but most of the energy of the fire went up the flue. In the modern steam-engine, the heat travels through a maze of water pipes (Figure 20). Thus much more of the energy becomes effective and much less of it goes up the stack.

Usable energy costs money whether it comes from coal

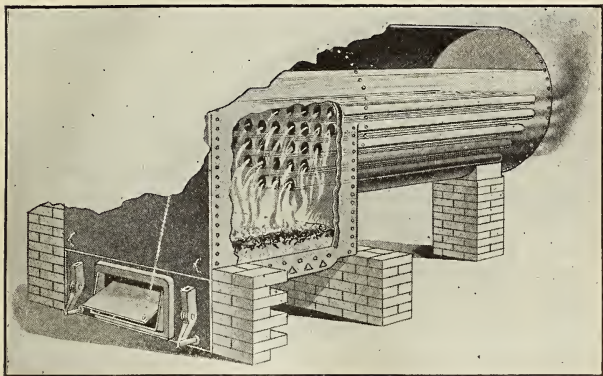


FIGURE 20.—DIAGRAM OF CONSTRUCTION OF MODERN BOILER

Much more of the energy becomes effective.

or from men's muscles. Factories often find it possible to install new machinery and to pay for it in a few months or a few years out of the saving of energy.

Can you find examples of such devices in the home, on the farm, in the office, or in the factory?

In reality, however, no energy is ever lost or destroyed. It may be lost in the sense that it does not serve man's immediate purpose, but it has not gone out of existence. The same thing may be said of energy that was said of matter. Man can neither create it nor destroy it. He can only transform it. This truth has been determined

by a vast amount of the most careful investigation, and is called the *law of the conservation of energy*.

SUMMARY

Whatever has the capacity to overcome resistance, to do work, is a form of energy. The sun is the source of all the usable energy of the earth. If a body has the ability to do work without actually being at work, it is said to have potential energy. The energy of a body at work is called kinetic.

There are different forms of energy, such as heat, light, electricity, gravitation, chemical energy, etc. Energy can neither be created nor destroyed, but one form of energy may readily be changed into another.

When man transforms one kind of energy into another, there is always a "loss of energy." This does not mean that the energy passed out of existence but that the "lost" energy was not utilized in accomplishing desired work. Usable energy costs money and the constant effort of inventors and engineers is to direct to useful purpose as much of the energy as they are able to control.

QUESTIONS

What is energy?

What is our main source of energy?

How can we trace the energy in coal, wood, oil, falling water, etc., to the sun?

What is potential energy? Kinetic? Illustrate both.

What is meant by transformation of energy? Name some common examples of it.

What is meant by "loss of energy"?

Is energy ever destroyed? If not, what becomes of it?

CHAPTER V

MAN'S CONTROL OF HEAT

A man does not marvel at the things he sees frequently, even though he be ignorant of their causes.—Cicero.

Heat is the most common form of energy that man has learned to control. When it was first studied, it was thought to be an invisible fluid without weight which saturated bodies in some mysterious way, as water saturates a sponge. This fluid was supposed to be driven out by pounding or rubbing. Even the primitive savage knew that fire could be obtained by rubbing two dry pieces of wood together.

About the close of the eighteenth century an American, Count Rumford, who was boring some cannon for the Bavarian government, showed that the amount of heat seemed to be entirely dependent upon the amount of grinding or mechanical energy expended. The old theory of a fluid prevailed, however, until about the middle of the nineteenth century. About that time a great English experimenter by the name of Joule proved conclusively that the amount of heat was owing directly to the amount of energy which apparently disappeared into the heated body. In short, heat was shown to be a form of energy which might result from the transformation of some other form of energy. Heat is a form of energy which manifests itself in the motion of molecules of matter. If a condition could be reached where there was no molecular motion, there would be no heat. (Page 60.)

We have seen in Experiments 16 and 17 that heat may be produced by chemical means, and by rubbing or friction. Later we shall find that there are other means

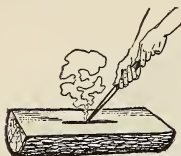


FIGURE 21

of producing heat. But it seems most natural to associate the idea of heat with fire, and it is difficult to realize that so common and useful a servant as fire has not

always been subject to ready control. Yet how would you proceed to build a

fire to-day if you found yourself alone and cold, without matches, in the middle of a forest?

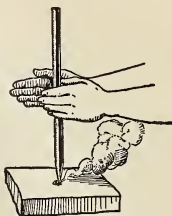
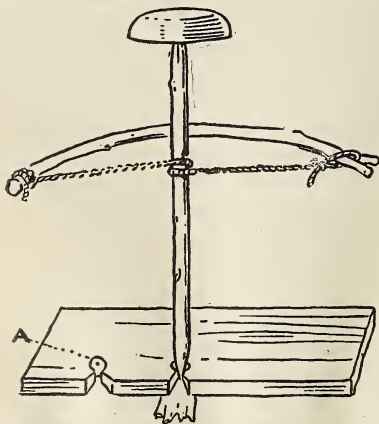


FIGURE 22



BOY SCOUT OUTFIT FOR MAKING FIRE WITHOUT MATCHES

At A is a hole made in producing fire.

it rapidly back and forth the length of the groove. (Figure 21.) Do you produce any smoke? If not, feel the point of the stick and the groove. Are they warm?

I. THE ART OF FIRE MAKING

Experiment 19.— Whittle a pointed stick out of hard dry wood. A dry lilac branch will do, or a stick from a maple, ash, or elm tree. Choose a dry board of soft wood (poplar, willow, pine, or fir). With a large nail make a narrow, shallow groove in the surface of the board into which the point of the hardwood stick will fit. Place the point of the stick into the groove, press down on it and rub

This was the primitive method of producing fire. The fire-borer (Figure 22) was the more common device, and it is still used by uncivilized tribes in South American jungles and in the South Sea Islands. The ability to produce fire is older than the oldest records of history. We do not know how man first came into possession of the secret, but it is probably the most important single achievement of man's intelligence. The increasing control and use of fire have gone hand in hand with advancing civilization. Fire has enabled man to conquer the metals, and so it is primarily responsible for all the progress we have made over the men of the Stone Age.

Assignment.—Read the opening pages of any good Ancient History and report on how men lived in the Stone Age.

Voluntary Project.—To make a rubbing-stick fire. Report the method and results to the class. Full instructions may be found in Official Handbook of the Boy Scouts of America.

Kindling Temperature.—Experiment 20.—Suspend a paper cup or a paper bag full of water over a gas or alcohol lamp. (Figure 23.) If you are careful to confine the flame only to that portion of the bag that is in contact with the water, you can bring the water to a boil without burning the paper.

This is because the bag can not get much hotter than the water it contains, and the hottest temperature water can reach is below the point at which paper will take fire. We have found by experience that the building of a fire is a gradual process. A certain amount of heat is necessary to get things to burn. Two pieces of wood have to be rubbed until they are very hot before the wood dust shows a spark. We use a match to light paper, the paper "sets fire" to the small pieces of kindling, and the flaming kindling material makes the coal hot enough to burn.

The temperature at which a substance will take fire is

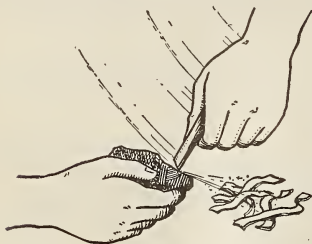


FIGURE 23

called the *kindling temperature* of that substance. Kindling temperatures of different substances vary greatly. That of white phosphorus is a little below the temperature of the human body, and so phosphorus is a dangerous thing to handle. The kindling temperature of iron is many hundreds of degrees.

Experiment 21.—Strike a piece of flint a glancing blow with another piece of flint. What is the result?

For centuries man chipped flint with flint to manufacture arrow-heads and other weapons and tools. It is probable that in this way he came to use flint for starting fires.



STARTING A FIRE WITH FLINT AND STEEL

Our forefathers used the flint and steel method of starting fires. Each household had a covered metal box, called a tinderbox. Several layers of linen were cut to lie flat in the box; the box was tightly covered, and then placed on live coals in the fireplace. This charred the linen without burning it. Charred linen has a very much lower kindling temperature than the uncharred cloth, and so catches the spark very readily. Until less than a hundred years ago this was the prevailing method of obtaining fire.

Matches.—**Experiment 22.**—Examine a “bird’s-eye” match. What are its three visible parts? Try to strike it on the black portion of the tip (called the bulb) without touching the “bird’s-eye.” Does it light? Strike the “bird’s-eye” tip very lightly on a wood surface. Increase the pressure, stroke by stroke, until the match lights. Notice how each portion takes fire from the preceding portion.

An ordinary "bird's-eye" match is made by dipping a soft wood stick about a half inch into melted paraffin, then into a mixture containing potassium chlorate (the black part of the tip or bulb) and finally into a mixture that contains red phosphorus, or a phosphorus compound, mixed with ground glass (the "bird's-eye").

The ground glass in the tip causes friction with the surface on which it is struck. The heat of friction ignites the phosphorus which, as has been said, has a low kindling temperature. The potassium chlorate when heated gives off oxygen (Experiment 11), which increases the intensity of the flame, thus raising the paraffin to its kindling point. The burning paraffin, in turn, raises the temperature of the soft wood to its kindling point.

The invention of the friction match has made the production of fire easy and certain. It has been one of the great factors in making life comfortable. The old sulphur match was the first kind of friction match. It came into use about ninety years ago.

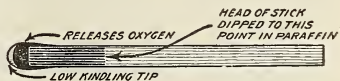


DIAGRAM OF A "BIRD'S-EYE" MATCH

The sulphur match burned so slowly and uncertainly and gave off such disagreeable fumes that the "parlor match" came into use.

In the parlor match, *yellow phosphorus* was used in the tip. This had such a very low kindling point that it was dangerous to carry or to ship the matches that contained it. Besides, yellow phosphorus is a terrible poison, which produced in the matchmakers a dreadful disease of the jawbone. For those reasons, the use of yellow phosphorus in the manufacture of matches has been abolished by practically all civilized countries. The *red phosphorus* or the phosphorus compound now used is not poisonous, and it has a higher kindling temperature.

Safety Matches.—Since friction against any rough surface will ignite the ordinary match, nibbling mice and busy-fingered children have often started disastrous fires with them. Because of that the “safety match” was invented, which will not ignite by friction on any ordinary rough surface.

Experiment 23.—Cut the “bird’s-eye” tips off two “strike anywhere” matches, leaving only the bulb of black compound on the sticks. Be careful not to ignite the matches. (Caution: Do not throw the tips carelessly away; burn them.) Now try to strike one of the matches by rubbing the black compound on any rough surface. Strike the other match on the striking surface of a safety match box.

You see that what corresponds to the low kindling “bird’s-eye” on the “strike anywhere” match is on the side of the safety match box. The ordinary match minus its kindling tip resembles the safety match.

On the tip of the safety match there is no phosphorus nor phosphorus compound, but only substances that will burn readily and that contain a great deal of oxygen. The side of the match box is coated with several substances, among which is red phosphorus. Red phosphorus can easily be ignited by friction with some substance that is rich in oxygen (potassium chlorate). The potassium chlorate on the tip of the safety match strikes a spark out of the red phosphorus on the box, and this spark ignites the match head.

II. THE NATURE OF FIRE

Experiment 24.—Wind a short piece of wire around a stub of a candle. After lighting the candle, lower it into a wide-mouthed bottle. Insert a stopper into the mouth of the bottle. Does the candle continue to burn or does it begin to smoke and finally go out?

From the foregoing experiment it appears that a supply of air is necessary for the burning of the candle. Ex-

perience shows that this is true of all forms of burning that are familiar to us.

Experiment 25.—(Teacher's Demonstration.)—Mix two parts of potassium chlorate with one part of manganese dioxide. Half-fill a test tube with the mixture. Arrange the apparatus for this experiment exactly as shown in Figure 24, making sure that all connections are tight. Fill a bottle with water and invert it over the delivery tube. Tap the test tube so that the mixture lies out the length of the tube.

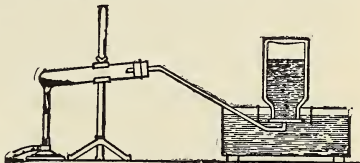


FIGURE 24

Apply a low flame to the end of the tube nearest the cork. The air will be driven off first. Oxygen will then be liberated from the potassium chlorate and will bubble up into the receiving bottle, displacing the water. (We learned in the study of the match that potassium chlorate is rich in oxygen and that heat liberates the oxygen from the compound.)

Regulate the heat so that the bubbles will come off in slow succession but not too slowly. When you have filled a bottle, slip a glass cover over its mouth, remove it from the trough, and lay it aside, right side up and covered. In this way, fill three bottles. Two will probably be all that are needed, but it is well to have a bottle in reserve for repeating any part of the experiment.

Provide a fourth bottle, containing nothing but air.

Bottle 1.—Light a splinter of wood and watch it burn in air for a moment. Blow out the flame and thrust the glowing ember into the bottle of oxygen. Does it burn more fiercely? Withdraw the splinter, blow out the flame and thrust the ember in again. Repeat this operation until the splinter no longer takes fire when it is thrust into the bottle. Do you conclude that the oxygen is exhausted? Thrust the glowing ember into a bottle containing nothing but air. Does it burst into flame as it did in the oxygen?



FIGURE 25

Bottle 2.—Attach a piece of sulphur to a short piece of picture wire. Ignite the sulphur by holding it in a flame, and then thrust it into the bottle of oxygen. (Figure 25.) Does the sulphur burn more brilliantly? Does the wire also burn? If so, the sulphur has

burned so fiercely that it has raised the wire to its kindling temperature.

In the experiment just performed, we found that substances which do not burn rapidly in air burn fiercely in oxygen. Experiments have shown that burning is the result of chemical union of atoms of oxygen with atoms of other substances. Kindling temperature, we see then, is the temperature at which atoms of a substance unite rapidly with atoms of oxygen. Fortunately for us, only about one-fifth of the air about us is oxygen. If it were pure oxygen, a fire once started would burn up iron as readily as it now does wood.

Fuel Elements.—Experiment 26 (A).—Hold a clean cold glass or porcelain plate in a candle flame for a few seconds. What do you find on the plate? (Figure 26.)

(B).—Hold a clean, cold, dry funnel over a candle flame. Hold it there until drops of water form inside the funnel; but not until the funnel gets hot, or the drops of water will evaporate again. (Figure 27.)



FIGURE 26

The black substance on the plate is almost pure carbon.



FIGURE 27

The cold plate reduced the temperature of the atoms of carbon below their kindling point, and so they were deposited unburned on the plate. The water found in the funnel shows that there must be hydrogen burning in the flame, since only hydrogen combined with oxygen can produce water. Two atoms of hydrogen unite with one of oxygen to form water, and so chemists call water, H_2O .

When carbon burns, its atoms unite with atoms of oxygen to produce a gas called carbon dioxide. In a molecule of carbon dioxide there are two atoms of oxygen for every atom of carbon, and so chemists call carbon dioxide, CO_2 .

We see that the paraffin in the candle is a compound

that contains both hydrogen and carbon. These two elements burn very readily in air. They are found in all common fuels and are sometimes called *fuel elements*. Both of them readily unite under ordinary conditions with oxygen, and the chemical action produces heat.

Burning, also called *combustion*, is therefore a chemical process. If it is rapid, as in fire, it gives off noticeable heat and light. If it is slow, as in rusting (page 65), heat is produced just the same, but so slowly that it is not noticeable.

The reason why stone, dirt, sand, iron, etc., will not burn in air is that they lack the fuel elements. Water and carbon dioxide are burned hydrogen and carbon. Therefore they can not serve as fuel. In fact, they may serve, as do ashes, dirt, or sand, to put out fire.

III. CONTROL OF FIRE

When fire gets out of control it ruthlessly destroys almost everything it can touch. The control of fire is, therefore, exceedingly important. We have seen (page 90) that fire cannot exist unless oxygen is present. Closing the draft of a stove, for example, cuts down the supply of oxygen. Therefore to control fire it is only necessary to shut off the air which contains the oxygen required for combustion.

Carbon Dioxide as Fire Extinguisher. — Experiment 27.—(Teacher's Demonstration.)—

Place eight or ten chips of marble or limestone in a strong wide-mouthed bottle. Barely cover them with water. Fit the bottle

with a two-holed rubber stopper, having a thistle tube extending through one hole and a bent delivery tube through the other. The thistle tube should extend far enough down into the bottle for its lower end to be submerged in the water. Con-

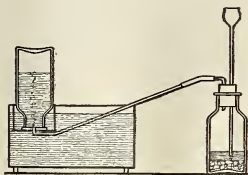


FIGURE 28

nect the delivery tube with the shelf of a pneumatic trough by means of a rubber tube. (Figure 28.) Provide two eight-ounce wide-mouthed bottles filled with water.

Pour hydrochloric acid down the thistle tube *a few drops at a time*. Let the first bubbles that come from the delivery tube escape, and then invert one of the water-filled bottles over the end of the delivery tube. When the bottle is full of gas, slip a glass cover over its mouth, quickly turn it right side up and set it aside covered. In this way fill the other bottle and set it aside. The two bottles are filled with *carbon dioxide*.

(Alternative Home Method.—Put two teaspoonfuls of baking soda into a quart fruit jar. Pour four tablespoonfuls of vinegar over the soda. Cover the jar immediately with a sauce dish. Let it stand for two or three minutes.)

Does the gas differ in appearance from air? Sniff it. You notice it has no odor. (In the home experiment, you will not be able to determine this because of the odor of the vinegar in the bottle.) Touch a match to the mouth of the bottle. Does it take fire like illuminating gas? Plunge a lighted splinter into the bottle. Does the gas support combustion as oxygen does?

Slowly overturn a bottle of the gas on the flame of a candle, just as if you were pouring water on the flame. Does it extinguish the candle?

Since you can pour it like a liquid, do you conclude that carbon dioxide is heavier or lighter than air? Would carbon dioxide be more effective in putting out a fire on the floor or on the ceiling of a room? There is very little carbon dioxide gas in the air. What would be the effect upon ordinary combustion, if the amount of carbon dioxide in air were largely increased?

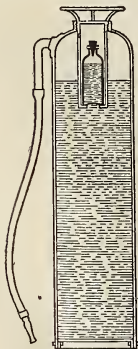
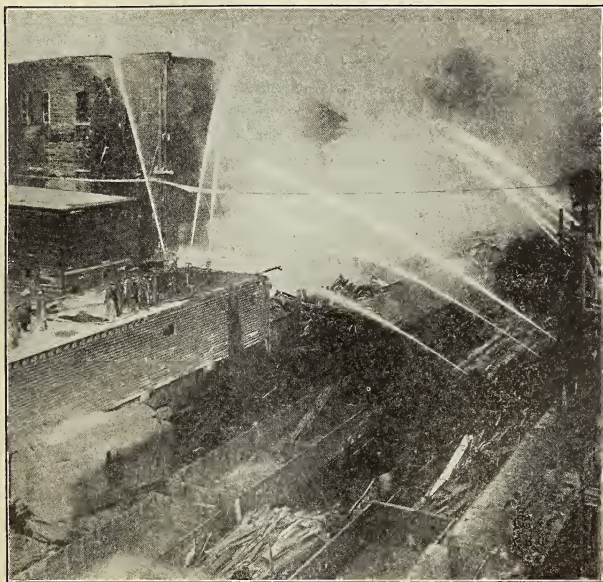


FIGURE 29.—
CHEMICAL FIRE
EXTINGUISHER

Commercial Devices.—The ordinary chemical fire extinguisher (Figure 29) consists of a strong metal cylinder nearly filled with a solution of baking soda. Held firmly in the top of the cylinder is a bottle of sulphuric acid. There is an opening in the top of the cylinder which is connected with the nozzle by means of a short, strong rubber tube. When the extin-

guisher is to be operated it must first be inverted. The acid falls out of the bottle, and mingling with the solution of baking soda rapidly generates carbon dioxide. The pressure of this generating gas forces the solution mixed with the gas out of the nozzle.



FIRE OUT OF CONTROL

Fighting a great conflagration at the Chicago stockyards.

Another very commonly used extinguisher, which is compact enough to be convenient for automobile use, is filled with a liquid that contains carbon tetrachloride. When this liquid comes in contact with heat, it is readily converted into a heavy gas which smothers the fire just

as carbon dioxide does. This machine is operated like a simple hand-pump.

Class Project.—To operate a fire extinguisher.—Every pupil of junior high school age ought to know how to operate a fire extinguisher.

Every modern fire extinguisher has explicit directions for operating it printed on the metal container. These directions should be followed to the letter.

Build a small fire in the open, away from all buildings, and use a fire extinguisher to smother it.

See that the extinguisher is refilled according to directions.

Other Means of Controlling Fire.—When water is put on a fire it not only shuts off the supply of oxygen but it also cools the burning material below its kindling temperature. Water, however, is not serviceable for extinguishing such substances as burning oils, since the burning oil floats on the water and the expansion of any generated steam throws the flaming oil about and thus spreads the fire. In a case of this kind, sand or a woolen blanket serves the purpose better.

Wool does not burn readily, and when the blanket is thrown over the burning oil, the air is shut off and the fire put out. If one's clothing takes fire by accident, one should never run. A rug or a blanket rolled about the body is the most effective means of putting out the fire. If one is outdoors, rolling in the dust or heaping dust on the flames, will cut off the oxygen supply. The chief thing to remember is to cut off the air supply immediately.

Spontaneous Combustion.—Certain substances very readily unite with the oxygen of the air at ordinary temperatures and, by so doing, of course produce heat. If the heat thus produced does not escape, the substances will in time be raised to their kindling temperature and will take fire. This is called *spontaneous combustion*.

Linseed oil used by painters is a substance which readily

oxidizes. Accumulations of rags saturated with such oil will gather heat of oxidation (if in a place where there is no great movement of air) until the kindling temperature is reached, and a fire is started. Sometimes the dust in the center of a great pile of coal produces heat enough by its oxidation to start a fire in the coal. "Souring" of hay is a form of slow oxidation. It is caused by storing hay before it is thoroughly dried. Farmers know this, but they sometimes "take a chance," to their own sorrow. Damp newspapers and magazines stored in a warm unventilated corner may gather enough heat to reach their kindling point. Foresters know that a great pile of leaves in a protected nook may cause disastrous forest fires. Spontaneous combustion stands *fifth among the major causes of fire* in the United States. The annual loss from this cause alone is about ten million dollars a year.

Home Project.—See if rags containing oil or paint are thrown into dark unventilated corners. Are paint, varnish, or oil-stained working clothes thrown in a heap or hung very close together in an unventilated place? Where are newspapers stored? Are they perfectly dry? See if coal is stored in unventilated wooden bins. If you live on a farm, see if any hay was stored green or damp. If so, dig down into it and see if it is noticeably warm underneath. Help provide remedies for dangerous conditions if they exist. Report to the class the results of your activities.

IV. THE MOST COMMON FUELS

How a Candle Burns.—Experiment 28.—Hold a match above the wick of a paraffin candle and slowly bring it down to the tip of the wick. Does the paraffin in the wick melt before the wick lights? Let the candle burn steadily for two or three minutes. Now light a match and hold it in readiness. Blow out the candle and immediately hold the lighted match in the smoke of the extinguished candle about $\frac{1}{2}$ inch above the end of the wick. Does the gas light?

Put the candle in a place where there is no draft and allow it to burn until the flame becomes steady. Notice that there is a dark,

cone-shaped space between the wick and an outer cone of yellow flame. (Figure 30.) Hold one end of a small glass tube in the dark space. Apply a lighted match to the other end of the tube. Does the gas there take fire?

Is there liquid in the cup-shaped depression around the wick? Is this liquid burning? Is the solid paraffin burning?

In the burning candle we see a fuel in three forms—solid, liquid, and gas. The foregoing experiment shows that it is only the gas from this fuel that burns. The heat of the match is sufficient to melt the paraffin in the wick and to start changing the liquid to a gas. The heat

of the flame thus started slowly melts the solid paraffin below to liquid form. The liquid ascends the candle wick as ink will ascend a lump of loaf sugar. (We shall study later why the liquid ascends. Just now our purpose is to study the flame.) As the liquid ascends toward the flame, the intense heat changes it into a gas. This gas steadily diffuses (spreads out) from the wick and feeds the flame.



FIGURE 30

What Coal Gas Is.—Experiment 29.—(Teacher's Demonstration.)—Fill a test tube $\frac{2}{3}$ full of finely powdered soft coal. Close the test tube with a one-hole stopper, through which is passed a short glass tube. Incline the test tube gently so that the mouth of the tube is slightly lower than the end containing the coal. Apply heat to the end of the test tube containing the coal, slowly at first, and then more and more intensely. Apply a match or lighted taper every few seconds to the end of the tube. Does the vapor coming from the glass tube burn? When vapors cease to come from the tube, examine what is left.

You have produced in this experiment a crude coal gas. What remains in the tube after the fuel gases have been driven off are coke and coal tar.

To produce coal gas commercially, crushed coal is placed in long, narrow, box-shaped ovens that are airtight. These ovens (or "retorts") are built side by side in blocks of forty. On each side of each oven are long narrow flues in which gas is burned to heat the coal in the retorts. The intense heat produced by these burning gases drives off coal gas, tar, ammonia, and oils. These products are all saved and sold for various purposes. The gas is stored in large tanks that disfigure the landscape in every large city. The coke remaining in the ovens is a very valuable fuel. A ton and a half of coal produces about a ton of coke and a half ton of gas and the other "by-products" mentioned. The coal gas is a mixture of hydrocarbon gases.

What Makes Part of a Gas Flame Yellow.—Experiment 30.—Cut down the air supply from the holes at the bottom of a Bunsen burner until the flame is yellow. Increase the air supply until the flame is blue. Now fill a small tube with finely powdered charcoal and blow it through the blue flame. How is the color of the flame changed?

Cut down the air supply again until the flame burns with a yellow light. Observe this flame closely. At the base of the flame, you will see a faint blue flame. This really forms a thin cone that surrounds the entire flame though it is not so easily seen at the top. Inside this is the cone of yellow flame, and inside this is the cone of gas that is not yet aflame. The same things may be noticed in the candle flame.

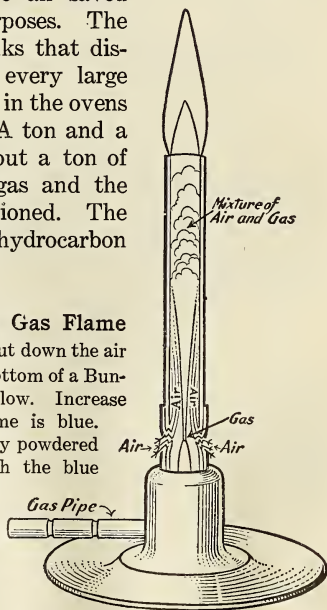


FIGURE 31.—DIAGRAM OF A BUNSEN BURNER

The outside blue flame is the hottest, because there the mixture of gas is most nearly perfect for complete combustion. Inside this is the yellow flame, not so hot, and inside the yellow cone of flame is the unburned gas which the air can not reach.

When the powdered carbon was blown through the flame of the Bunsen burner, it flashed yellow. This shows what it is that produces the yellow light of a candle or a lamp.

Heat causes hydrocarbon compounds (compounds con-

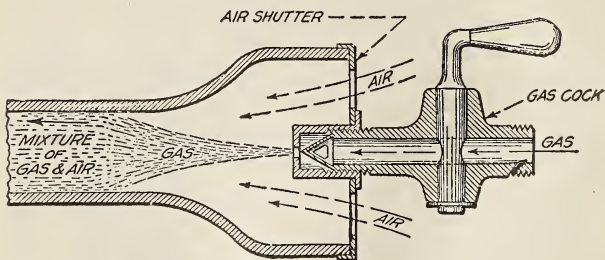
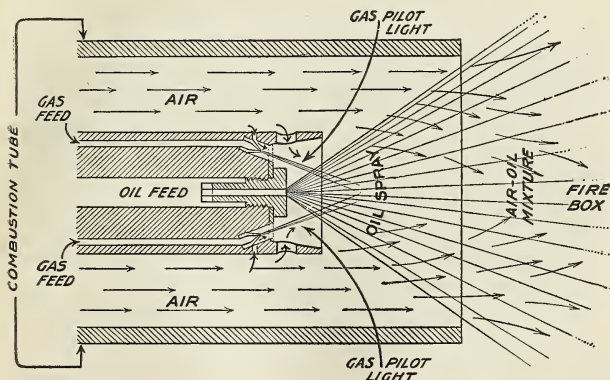


FIGURE 32.—DIAGRAM OF A GAS BURNER

taining hydrogen and carbon) to break down, thus releasing hydrogen and carbon. The hydrogen burns quickly. Some free carbon within the flame may be brought to a glowing state before it has a chance to unite with oxygen. This glowing carbon produces the yellow light of a gas flame. When the carbon reaches the outer area of flame where oxygen is abundant, it burns. But if the oxygen supply around the flame is low, some carbon passes away as smoke.

Devices for Mixing Air with Fuel Gases.—In burning any gas, the chief problem is one of mixing it with the right proportion of air. Study the accompanying diagrams of a Bunsen burner, a gas stove burner, and the feed of a domestic burner of fuel oil. (Figures 31, 32, 33.) Explain how the mixing is accomplished in each case.

Safety First in the Use of Gases.—A mixture of air and any hydrocarbon gas is explosive, when the mixture is right and the temperature is high enough. It follows that a leak in a gas pipe or the evaporation of gasoline or naphtha into a closed room may produce a roomful of explosive mixture. The temperature at which these gases in particular will flash is so low that the fire of a stove, the



Courtesy Wayne Tank and Pump Company

FIGURE 33.—DIAGRAM OF THE FEED OF A DOMESTIC BURNER OF FUEL OIL

heat of an electric iron, or the mere lighting of a match may produce a terrific explosion. There is still another danger that attends the escape of gas into a closed room—death by asphyxiation.

Good kerosene does not evaporate so readily as gasoline nor flash at so low a temperature, and so it is safer for use in lamps or stoves. But if kerosene is poured on hot coals to revive a fire, its temperature is raised so quickly that it may be suddenly transformed into a gas and flashed into an explosion. Kerosene is dangerous kindling material.

One of the gases that exist in small quantities in coal

gas is carbon monoxide. This gas is a deadly poison. We have learned that if carbon is completely burned, one molecule of it combines with two of oxygen to form carbon dioxide (CO_2) (page 90). When combustion is imperfect, one atom of carbon unites with one atom of oxygen to produce carbon monoxide (indicated by chemists as CO). As oxygen in the furnace draft goes through a bed of red-hot coals, this gas CO often forms. When CO reaches the top of the bed of coals where there is more air it may burn with a blue flame to form carbon dioxide (CO_2).

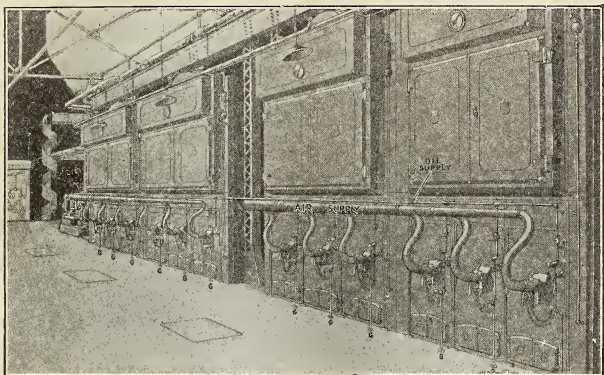
At night furnaces and stoves are generally banked (piled high with coal) to keep fires alive until morning. The upper part of the firebox is cold and so the carbon monoxide that forms in the glowing coals below has no chance to burn. It passes up the chimney unless the draft is obstructed. If the damper in the flue is turned too far it may force the smoke and carbon monoxide back through the feed door. Deaths have resulted in this way from carbon monoxide poisoning in *unventilated* sleeping rooms.

In an automobile engine, conditions are such that perfect combustion is not possible. As a result, only comparatively little of the carbon in the gasoline gas is completely burned, producing CO_2 . Much of it is only partly burned, producing great quantities of CO , while some of the carbon is not burned at all but is left to clog certain parts of the engine. The amount of carbon monoxide that escapes from the exhaust of an automobile engine is so great that it is dangerous to run an automobile engine in a closed unventilated garage even for a few minutes. Newspapers frequently carry accounts of tragic deaths from this avoidable cause.

Fuels for Heating the Home.—Anthracite or hard coal is a coal from which most of the oils and gases have been

driven in the process of its formation. Anthracite coal and coke are excellent fuels because practically their only fuel element is carbon. This element produces a hot, almost flameless and smokeless fire. The burning of these fuels can be easily controlled by the ash-pit draft of a furnace or stove, and they do not lose much of their fuel value in gases that escape up the chimney.

Wood is too expensive to be considered in many sec-



Courtesy Wayne Tank and Pump Company

BATTERY OF BOILERS IN WHICH FUEL OIL IS BURNED

Notice that the small pipe carrying the oil supply is so placed that the temperature of the oil will be raised toward its kindling point before it reaches the combustion tube. The little pipes marked "G" convey gas for the pilot lights of the combustion tubes.

tions, except for burning in open fireplaces. It contains so many hydrocarbon gases that it burns with a cheerful flame, but it does not produce so much heat as most kinds of coal. *Cannel* coal burns very much like wood and produces about the same amount of heat. It is much used for open grate fires.

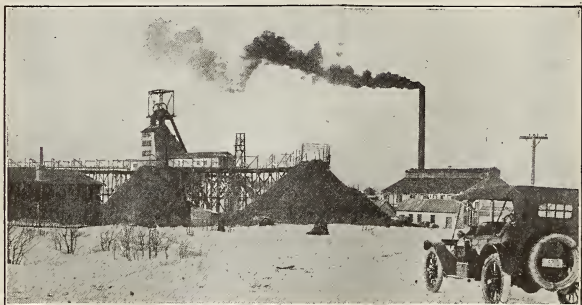
Burners are being perfected for the use of fuel oils in the heating of homes. Fuel oils are cheap and effective.

A good oil burner requires less attention than a coal burner. In the use of oil, dust, ashes, and almost all smoke are done away with.

Soft or bituminous coal is the fuel most commonly used. More care is required in firing with soft coal than with coke or with anthracite coal.

V. INTELLIGENT CARE OF SOFT COAL FIRES

Experiment 31.—After closing the holes at the bottom of a Bunsen burner, turn on the gas and light it. The flame is smoky. Heat a



Courtesy of Underfeed Stoker Company of America

BEFORE INSTALLING AN UNDERFEED FURNACE

When a blanket of fresh fuel is thrown on the glowing coals, great quantities of carbon and fuel gases escape as smoke. This may be likened to burning a candle upside down.

piece of wire in it. It heats slowly. Open the holes. The flame ceases to smoke. Place a wire in it. It heats quickly. Regulate the sizes of the openings until the greatest possible heat is obtained.

In Experiment 31 it was found that if the holes at the bottom of a Bunsen burner are closed so that an abundant supply of air (that is, of oxygen in the air) is not mixed with the gas, combustion is incomplete. When these holes are regulated so that the right amount of air is supplied, there is a hot flame and no smoke.

Smoke Nuisance.—Everyone knows that when a fire is completely covered with a fresh supply of soft coal, it smokes. Where the fresh coal (or “green” coal, as engineers call it) meets the glowing coals, the heat drives off the fuel gases very rapidly. Since there is not enough oxygen to burn all of these light gases where they are formed, the unburned gases rise to the upper part of the firebox. But here the temperature has been cut down below the kindling point of the gases. The result of this incomplete combustion is that great volumes of fuel gases



Courtesy of Underfeed Stoker Company of America

AFTER INSTALLING AN UNDERFEED FURNACE

In this furnace the fire is constantly above the fresh fuel, and the volatile gases and carbon are consumed as they pass up through the fire. This acts like a burning candle right side up.

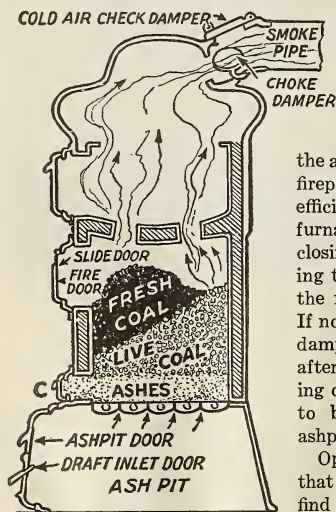
and finely divided carbon are set free and float away in the form of smoke.

This is responsible not only for the smoke nuisance but also for a great loss of available fuel, for it must be emphasized that *smoke is fuel*. It is estimated that in one city alone of over a half million inhabitants, the loss of heat owing to non-combustion of smoke is fully \$10,000,000 a year. This is aside from the tremendous total damage to clothing, house furnishings, and stocks of merchandise,

and from its menace to health. Hotels, office buildings, industrial plants, and railways are responsible for a great deal of the smoke of our cities, but homes and flat buildings produce by far the most of our disagreeable winter smoke.

It follows then that the place to begin the work of making a smokeless city is at home. Stop the belching of smoke from your own little chimney.

Home Project.—To study the maintaining and re-fueling of a fire.—With the aid of Figure 34, locate the various parts of your



Courtesy American Radiator Co.
FIGURE 34.—DIAGRAM SHOWING HOW
TO RE-FUEL A FIRE

furnace or heating stove. Is the ashpit kept clean? If the ashes become packed up against the grates, there is always danger of burning out the grates. What other disadvantage is there in allowing the ashpit to become packed? Is the firepot kept full? Thin fires are inefficient and wasteful. Does your furnace have an automatic device for closing the ash-door draft and opening the check-damper at the base of the flue? Is it working properly? If not, you are wasting fuel. Is the damper in the pipe kept partly closed after the fire is going? This checking of the draft gives the gases time to burn. Are the feed door and ashpit-door kept closed?

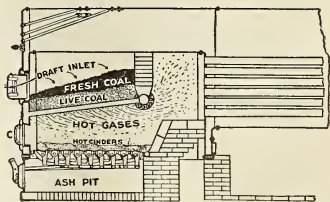
Open the feed door of a furnace that needs re-fueling. You probably find that the bed of coals is crusted over. This caking over is caused by the fusing, or melting together, of the tar products in the coal. Of course

this crust has to be broken to allow the draft to come through. Now if you will take the trouble to look up through the ashpit door at the grates above, you will find that the coals resting on them are

not bright, but dark or shaded. This is caused by ash. The ash is the unburnable mineral material in coal. It is the heaviest part of the coal, and when it is released it naturally falls to the grates. Do not thrust the poker down to the very grates "to stir up the fire and shake down the ashes." By so doing you lift cold ash from the grates up into the midst of the hot coals where it has a chance to fuse into large chunks, called *clinkers*. Shake the grates until they show red underneath. Remove the clinkers through the clinker door without disturbing the firebed above.

Gently heap up a bed of red coals at a point nearest where the hot gases leave the firebox. Do not cover up this heap of glowing coals, but fill all the rest of the firebox with fresh fuel. Close the feed door, and leave the draft in it open. The heap of glowing coals will raise the temperature of the gases to their kindling point and the open draft in the feed door will furnish a supply of oxygen to burn them.

Smokeless Furnaces.—Many cities require the use of smoke-consuming boilers in all large buildings. Most of these are so arranged that the gases formed where the supply of fresh coal meets the glowing coals, are conducted through the fire and largely consumed. (Figure 35.) The best of these are very efficient. They are so arranged that the fire and the hot gases come in



Courtesy Kewanee Boiler Co.

FIGURE 35.—DIAGRAM SHOWING RE-FUELING AND CONSTRUCTION OF A DOWN-DRAFT BOILER

contact with the largest possible amount of heating surface. Thus such boilers consume the fuel most thoroughly and make the best use of the heat obtained. But it must be emphasized that smokeless boilers are not automatically efficient. They must be fired intelligently. Some manufacturers of boilers are alive to this fact, and maintain expensive service departments for the instruction of the public.

Fire Prevention Project.—Are all furnace or stove-pipes in your home whole or tightly joined? Are there metal, stone, brick, or concrete bases under your furnace, stoves, and fireplaces? Are your stoves, furnace, and pipes well away from walls, woodwork, or draperies? Are your chimneys and flues clean and sound? Is your furnace large enough to heat your house in severe weather without forcing the fire and getting the furnace over-hot? Is anything inflammable stored near the furnace or against the chimney in the attic? Report on what you do to remedy faulty conditions. Remember that unintelligent installation or use of stoves, furnaces, boilers, stove-pipes, chimneys and flues cause an annual loss in the United States of between twenty and twenty-five million dollars.

VI. HEAT CAUSES EXPANSION OF SOLIDS, LIQUIDS, AND GASES

Experiment 32.—(Teacher's Demonstration.)—Fit a glass flask with a one-hole rubber stopper through which passes a glass tube about 20 cm. long. Place this on a ringstand so that the end of the tube extends down into a bottle nearly filled with water. (Figure 36.) Gently heat the flask. Bubbles rise in the water. Why? Why does water rise in the tube when the flask cools?

Experiment 33.—(Teacher's Demonstration.)—Fill the flask used

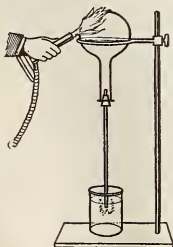


FIGURE 36

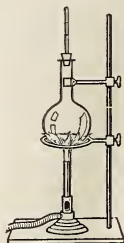


FIGURE 37



FIGURE 38

in the last experiment with colored water. See that the end of the glass tube passing through the rubber stopper is just even with the bottom of the stopper. Smear the lower part of the stopper with vaseline and insert it in the flask, being careful that the flask and a few centimeters of the tube are filled with the colored water and that there are no air bubbles in the flask. Mark, by slipping over a rubber

band, the end of the water column in the tube. (Figure 37.) Heat the flask. Does the water expand?

Experiment 34.—(Teacher's Demonstration.)—Pass the ball of a ball-and-ring apparatus through the ring. (Figure 38.) Notice how closely it fits. Heat the ball in a Bunsen flame for several minutes. See if the ball will now go through the ring. Explain why it does not.

We saw in these experiments that heat caused the gas, the liquid, and the solid to expand. Cooling had the reverse effect. When a substance is heated the molecules move more rapidly and strike each other harder. This drives the molecules farther apart and causes the substance to expand. (Pages 59 and 60.)

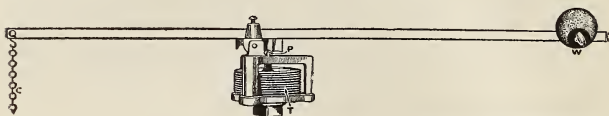
Practical Applications.—On every hand expansion and contraction due to changes in temperature must be taken into account. The ends of steam pipes are allowed to be free and are never attached firmly. The ends of the spans of long iron bridges are placed on rollers. In places where there are considerable ranges of temperature concrete sidewalks are cut into squares instead of being laid as continuous solid surfaces. When iron tires are fitted to wagon wheels they are first heated and then placed on the wheels and allowed to cool. Telephone wires are tighter in winter than in summer. For this reason they are not stretched taut when put up.

Automatic devices for controlling the temperature of living-rooms, of hot water tanks, etc., take advantage of the principle of expansion of a substance under heat. Such devices are called *thermostats*. (Figure 39.)

Substances usually expand as they change from the solid state to the liquid state, and contract when the process is reversed. Ice is a notable exception to this general rule, since when water freezes its volume increases. If it were not for this, ice would not float. Certain metals such as cast iron also have the property of expanding at

the moment of solidifying. Type metal is a mixture of metals that possesses this property. It is poured into the molds in a molten condition. When it solidifies it expands and forces itself into every available crevice, thus taking on the sharp outlines that type must have.

Substances always increase in volume as they change from a liquid to a gaseous state. Engineers roughly esti-



Courtesy The Fulton Company

FIGURE 39.—THERMOSTAT FOR STEAM BOILER

At C are seen a few of the links of the chain that attaches the lever of the thermostat to the draft inlet. The lever rests on the point P, and the weight W keeps the draft inlet lifted. When the steam pressure becomes great enough to expand the spring-like metal box T, the weight is lifted, the other end of the lever falls and the draft closes. The farther back the weight is placed the greater is the steam pressure required to lift it.

mate, for example, that a cubic inch of water makes a cubic foot of steam. It is the terrific expansion of water as it passes from the liquid to the gaseous state that is responsible for the power of the steam engine.

Experiment 35.—(Teacher's Demonstration.)—Heat a metal compound bar. It bends over on one side. The more the bar is heated the more it bends. (Figure 40.) A compound metal bar is made of two different kinds of metal riveted or welded together. The two metals do not expand at the same rate. The bending of the bar is the result of this difference between the two metals in the rate of expansion.



FIGURE 40

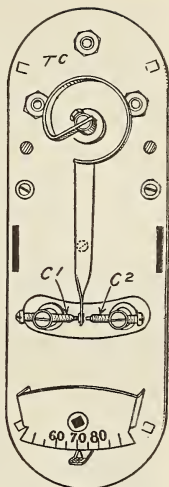
Various solids and liquids expand and contract at different rates. Platinum expands and contracts at almost the same rate as glass. When platinum and glass are fused together they expand

and contract almost as one substance. For this reason, in the manufacture of incandescent lamps, platinum is the only substance that can be used to pass through glass to carry the electrical current to the filament within. Other metals contract either more than the glass and thus let air into the bulb, or less and thus break the glass. One reason why mercury is used in thermometers is that it changes rapidly in volume with changes in temperature.

Different parts of the same substance will expand at different rates according to the amount of heat applied. When experienced housewives wash glasses in hot water, they do not dip them slowly; they plunge them in quickly so as to allow them to expand at the same rate throughout and thus to prevent their breaking. This explains why it is unwise to pour boiling water slowly into a cold glass, or cold water slowly into a hot glass.

VII. HOW TEMPERATURE AND HEAT ARE MEASURED

Measurement of Temperature.—With the steady advance of science, accurate means of measuring temperature become more and more necessary. In almost all industrial operations, temperature plays some part. The temperatures at which important chemical and physical changes occur are accurately known. The wise farmer has occasion to keep careful watch



Courtesy Minneapolis Heat Regulator Co.

THERMOSTAT THAT MAKES USE OF A COMPOUND BAR

The coil, TC, to which the pendulum is attached, is a compound bar. As the temperature of the room in which this thermostat is located rises, the coil is bent so that it switches the pendulum over to the point C2, where it makes an electrical contact that results in shutting off the drafts of the furnace. As the room cools, the coil tends to resume its original shape and to switch the pendulum back to C1. This electrical contact results in opening the drafts of the furnace

of the temperature and to follow the predictions of the weather bureau. In the operation of the incubator and the care of dairy products, temperature must be carefully taken into account. Temperature tells the physician much about the condition of his patient. Even in cooking, temperature is no longer a matter of guesswork. Modern ovens are equipped with thermometers or thermostats and directions for cooking include the degree of temperature and the time necessary for the operation.

It has been found that most substances expand uniformly through ordinary ranges of temperature, so that if expansion or contraction is measured, we are able to determine the change of temperature.

Instruments arranged to show changes in temperature by the amount of the expansion or contraction of certain materials, are called *thermometers*. These may be gas, liquid, or metal thermometers.



FIGURE 41

Experiment 36.—(Teacher's Demonstration.)—Fill a four-inch ignition tube with mercury and insert a one-hole rubber stopper having a straight glass tube extending through it and about 20 cm. above it. (Figure 41.) It may be necessary to cover the stopper with vaseline to keep out air bubbles. When the stopper was inserted the mercury should have risen a few centimeters in the tube. Mark with a rubber band the end of the mercury column. Gently warm the ignition tube. Does the mercury column rise? Cool the tube. Does the mercury column fall? Explain. We have here a crude thermometer.

The substance whose expansion is most commonly used to measure the degree of temperature is mercury. This expands noticeably for a slight increase in temperature and the amount of its expansion can be very readily determined. The ordinary thermometer consists of a

glass tube of uniform bore which has a bulb at one end. The bulb and part of the tube are filled with mercury. The remaining part of the tube is empty, so that the mercury can freely rise or fall. When the temperature rises, the mercury expands and rises; when the temperature falls, the mercury contracts and sinks.

Centigrade and Fahrenheit Scales.—In any scale for the measurement of temperature there must be certain fixed points known to everybody as a basis of comparison of temperatures. These definite points have been established as the *freezing and boiling points of water at sea level*.

There are two kinds of thermometer scales commonly used, the Centigrade and the Fahrenheit.

The one which is used almost exclusively in scientific work and in those countries where the metric system of weights and measures has been adopted, is called the *Centigrade*. In this scale the point to which the mercury column sinks when submerged in melting ice is marked 0° , and the point to which it rises at sea level when immersed in unconfined steam (the boiling point of water) is 100° . A degree Centigrade, then, is $\frac{1}{100}$ the distance the column expands when heated from freezing to boiling.

The common household thermometer of this country and England is the *Fahrenheit* thermometer. It is named after its inventor, who about two hundred years ago began the making of thermometers. He found that by mixing ice and water and salt he obtained a temperature much lower than that of freezing water. This temperature he took as his zero point. In this scale the point at which ice and snow melt



FIGURE 42.
—CENTI-
GRADE AND
FAHREN-
HEIT
SCALES
COMPARED

is marked 32° , and the point at which water boils at sea level is marked 212° . The distance between the boiling point and freezing points is divided into 180 equal parts, or degrees. A degree Fahrenheit, then, is $\frac{1}{180}$ the distance the

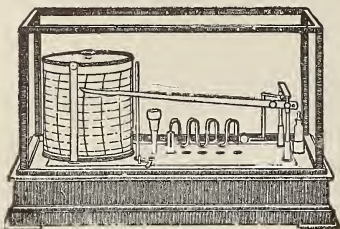


FIGURE 43.—A SELF-RECORDING THERMOMETER

column expands when heated from freezing to boiling, instead of $\frac{1}{100}$ as in the Centigrade scale. (Figure 42.)

There are a number of different designs of thermometers. Some are for measuring very high, others for measuring very low, tempera-

tures. Thermometers are also constructed so as to be self-recording. (Figure 43.)

Both the Centigrade and the Fahrenheit scale are used in later discussions in this book. The student has been accustomed to the English or Fahrenheit scale in everyday life, and so occasionally the use of this scale prevents unnecessary confusion. On the other hand, the Centigrade scale is preferred in scientific work, and, like all the metric scales, is the rational system. It is, therefore, used frequently hereafter in order to familiarize students with it. In occasional discussions where one scale is used, *approximate* equivalents in the other scale are added in parentheses.

To change *Fahrenheit to Centigrade*, subtract 32 from the number of degrees and multiply the remainder by $\frac{5}{9}$.

$$70^{\circ} \text{ F.} = (70 - 32) \times \frac{5}{9} = 21\frac{1}{9}^{\circ} \text{ C.}$$

To change *Centigrade to Fahrenheit*, divide the number of degrees by $\frac{5}{9}$ and add 32.

$$-10^{\circ} \text{ C.} = (-10 \div \frac{5}{9}) + 32 = 14^{\circ} \text{ F.}$$

Change the present reading of the Fahrenheit thermometer in your room to the Centigrade scale. If the water in a basin registers 140° Fahrenheit, what would be its temperature by the Centigrade scale? The normal temperature of a human body in health is 98° . What is its equivalent in the Centigrade scale?

Measurement of Heat.—*Temperature* must not be confused with *amount of heat*. The amount of heat in a spoonful of water at 100° C. would be much less than in a pailful at 10° . It would require more heat to raise a pond of water a small part of one degree of temperature than to raise a kettleful many degrees.

Experiment 37.—Provide three quart cans and a pound of fine No. 10 shot. Into each can put a *pound* of water freshly drawn from the faucet.

Tie the pound of shot in a cloth and attach the cloth to one end of a piece of picture wire. Lower the bundle of shot into can No. 1 and put the can over a flame.

While the water is coming to a boiling temperature, take and record the temperature of the water in cans No. 2 and 3 with a chemical thermometer. When the water over the flame reaches the boiling point, move the bundle of shot around in the water. When the water continues to boil in spite of this stirring, quickly transfer the bundle of shot to can No. 2 and the pound of boiling water to can No. 3.

Stir the contents of both cans thoroughly and again take the temperature of the water in each. Which mixture shows the greater increase in temperature—can No. 2 (the pound of water and the pound of shot) or can No. 3 (the two pounds of water)?

Although the pound of water and the pound of shot were at the same temperature (212°), the pound of water had a great deal more heat stored up in it than the pound of shot had. In other words, a pound of water must absorb very much more heat to reach any required temperature than does a pound of shot. For this reason we say that water has a much greater capacity for heat than shot has.

If a pound of water and a pound of olive oil are placed side by side in similar dishes on a stove, it will be found that the olive oil increases in temperature about twice as fast as the water. That is, it takes about twice as much heat to raise the temperature of water one degree as it does to increase the temperature of olive oil one degree. In fact water has a greater capacity for heat than almost any other known substance. This capacity of water for heat explains why large bodies of water, although their temperatures never greatly change, are able to absorb and to give out such great amounts of heat that they affect the climate of neighboring land areas.

Since the capacity of water for heat is so great, the capacity of other substances is measured in comparison with it. For instance, it takes .47 as much heat to raise any given mass of olive oil one degree as it does to raise a corresponding mass of water one degree. The shot in the experiment required only .03 of the amount of heat to raise it to 212° that the water required to reach the same temperature. These figures indicate the *specific heat* of olive oil and shot.

Explain why we fill hot water bags with hot water rather than with shot at the same temperature.

Units of Measure for Heat.—Since heat plays such an important part in the activities of the earth, it is necessary to have some unit of measure for it. Physicists have taken as a unit of measure the amount of heat required to raise the temperature of one gram of water one degree C. This unit is called the *calorie*. A large Calorie (spelled with a capital C) is a thousand times the small unit. That is, it represents the amount of heat necessary to raise a kilogram (1000 grams) of water one degree C. in temperature. The calorie is the unit used in scientific work. Food values in modern cook books are indicated in calories.

Amount of Heat Required to Melt Ice 115

The value of a food in calories indicates the amount of heat energy it will produce in the body.

Engineers in America and in England use a different unit in computing the heat values of fuels. This unit is the amount of heat necessary to raise the temperature of one pound of water one degree Fahrenheit. It is called the British Thermal Unit, generally referred to in conversation by its initials B-t-u, or written Btu.

Amount of Heat Required to Change Ice into Water.—

Experiment 38.—Fill two tin cups or beakers of the same size to an equal height, one with ice water and the other with a mixture of water and ice. Stir each with a chemical thermometer and make note of its temperature. Place the two vessels side by side on a stove or over Bunsen burners so adjusted as to give approximately the same amount of heat. (Figure 44.)

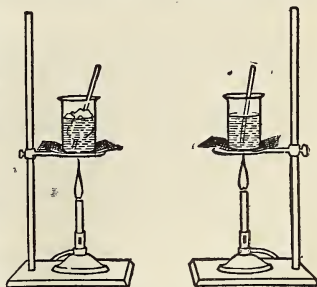


FIGURE 44

Stir the contents of each cup with a chemical thermometer from time to time and note changes in temperature in either cup. Keep this up until the ice melts. Do your notes show that like amounts of heat have

produced like changes in temperature in the two cups? What apparently became of the heat delivered to the cup containing the ice?

Continue to heat both cups after the ice is melted, stirring and noting the comparative temperatures. Is there now an approximately equal rise in the temperatures of the water in the two cups?

This experiment shows that heat is absorbed in melting ice and that the heat so absorbed does not raise the temperature of the water into which the ice is changed. As has been said, it requires one Btu to raise the temperature of a pound of water one degree Fahrenheit. Carefully performed experiments have shown that it requires 143

times that amount of heat to change a pound of ice into water, without raising the temperature at all. This explains why ice melting in a refrigerator takes so much heat from the air and the food about it and thus keeps them cool.

Amount of Heat Required to Change Water into Steam.

—Experiment 39.—Draw water from the faucet into a tin cup or beaker and put the vessel over a flame. Stir the water with a chemical thermometer, noting the increase of temperature until the water boils. Let it boil for several minutes, noting the temperature from time to time. Does the temperature increase after the boiling begins? What apparently becomes of the heat delivered to the water while it is boiling?

Experiment 39 shows that after water reaches the boiling point, heat will not increase its temperature further: it only serves to change the water into steam. Now consider how much heat is absorbed by the steam in the course of this change. While it takes one Btu to raise a pound of water one degree Fahrenheit, it requires 972 Btu, or 972 times as much heat, to change a pound of water into steam.

This absorption of heat that accompanies the changing of a liquid to a gas is the main principle used in the manufacture of ice. In this process liquid ammonia is changed to gas. A tremendous amount of heat is absorbed in the change. The machinery is so arranged that the heat absorbed is taken from water placed in cans ready for freezing. The water in each can, losing its heat to the changing ammonia, is transformed into a block of ice.

The amount of heat absorbed by a pound of ice in melting is given out again when the water freezes. Many of us have noticed that when we have a *quiet* snowfall, the temperature of the air usually rises. This is because heat is given out by the moisture of the air as it changes into snow. If there are no air currents to carry this heat

away, it warms the atmosphere around us. The heat absorbed when the water in a boiler is changed into steam is given out again when the steam changes back into water in the radiator.

Explain why we use ice instead of ice water in our refrigerators to keep food cool.

VIII. HOW HEAT IS TRANSFERRED

Some one has stated a truth playfully in saying that "no substance is ever selfish with the heat it possesses." Any hot object left for a long enough time in cooler surroundings will yield up its heat until it is of the same temperature as its surroundings. Any cold object placed in warm surroundings will receive heat until it is eventually of the same temperature as its surroundings.

If water is placed on a hot stove it will absorb heat until it passes away in steam. If hot water is allowed to stand in a room, it will give off its heat until its temperature falls to that of the room. When ice is placed in a refrigerator the heat of the contents of the refrigerator is yielded up to the ice and melts it. If a refrigerator could be so constructed that no warmth could reach its interior, the contents would eventually become as cold as the ice.

Conduction of Heat.—**Experiment 40.**—Cut off 15 cm. of No. 10 copper and No. 10 iron wire and the same length of glass rod of about the same diameter. Hold the copper and the iron wire, each by one of their ends, and place the opposite ends in the flame of a Bunsen burner. Which conducts the heat to the hand first?

Dip the iron wire into water to cool it. Wipe it dry. Now using the iron wire and the glass rod, repeat the experiment. Which of these two conducts the heat to the hand first? Which of these three should you say is the best "conductor" of heat?

Experiment 41.—Fill a test tube about $\frac{3}{4}$ full of cold water. Holding the tube by the bottom carefully heat the top part of the water until it boils. Be sure that the flame does not strike the tube above the water, else the tube will break. (Figure 45.) A little piece of

ice in the bottom of the test tube makes the action more apparent. A bit of wire gauze or a wire stuffed into the test tube will prevent the ice from coming to the surface. Water conducts heat poorly. The hot water does not sink. Do you conclude that the warm water is heavier or lighter than the colder water?

Through some substances heat travels rapidly; through others less rapidly, or even slowly. In Experiment 40, we found that heat traveled at different speeds along the different rods. In no case, however, was there any indication that particles of the rods traveled from one end to the other. In the boiling of the water at the top of the test tube, there was no indication that the water particles moved to the bottom of the tube.



FIGURE 45

What really happened in these cases is that where the heat was applied to each material, the motion of the molecules became more rapid. The heated molecules bumped with greater force against neighboring molecules and thus started them into more violent motion. This kind of heat transference is called *conduction*.

In transference by conduction each molecule "plays tag" with its neighbors, passing the heat energy on to the molecules that it strikes. If two *different substances touch each other*, the molecules of one substance may conduct heat to the molecules of the other; but the two substances must be touching each other or the method of transference cannot be called conduction.

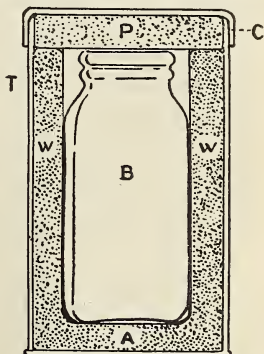
Good Conductors and Poor Conductors of Heat.—In the copper, the increased motion of the molecules was conducted rapidly from molecule to molecule until it soon reached the other end of the rod. We therefore call copper a good conductor of heat. In Experiment 41, the molecules of water at the top of the test tube were in the

most violent motion and yet practically none of this motion seemed to reach the water or the ice at the bottom of the tube. Water is therefore said to be a poor conductor of heat.

Experiment 42.—Fix a cork for a handle to one end of the copper wire used in the previous experiment. Make a handle of sheet asbestos or of asbestos cement for the iron wire. Hold the wires by their handles and thrust the opposite ends into the flame. Hold them there until the wires are visibly hot. Hold them there until the wires are visibly hot. Are your fingers protected from the heat?

The metals are the best conductors of heat, with silver, copper, and aluminum ranking very high. We use asbestos to cover pipes that convey steam or hot water to radiators, because asbestos is a poor conductor and will keep the heat in the pipes. Cork is used in the walls of a fireless cooker to prevent the escape of heat by conduction. Dry, dead air (that is, dry air not in motion) is one of the very poorest conductors of heat. When birds ruffle up their feathers on a cold day, the air spaces between the feathers keep the heat of their bodies from being conducted away so quickly. The dead air space between a storm window and a built-in window slows up the escape of heat by conduction.

During the war experiments conducted at the University of Minnesota proved that window shades carefully fitted and lowered to the sills conserve from twenty to



CROSS SECTION OF HOME-MADE
HOT AND COLD BOTTLE

B is a Ball-Mason jar; *T*, a three-pound coffee tin; *AWW*, asbestos cement walls lined with cheese-cloth; *P*, circular pad of newspapers quilted together; *C*, cover for tin. This will keep hot liquids hot or cold liquids cold for from 10 to 12 hours. Explain why.

forty per cent of the heat of a room otherwise lost. Why?

Many materials are poor conductors of heat because their texture is such that there are innumerable dead air spaces in their make-up. It can readily be seen that fur, sheep's wool, cotton wool, and feathers are poor conductors for this reason. Plaster, wood, asbestos, sawdust, paper, and leather are also poor conductors, largely because of their porous nature; that is, because of the minute dead air spaces in their make-up. Snow is an even poorer conductor of heat than air. Snow on the ground prevents the heat from leaving the ground and the ground from being deeply frozen. That is one reason why farmers like a snowy winter.

We may be as much interested in keeping heat away from some materials as in retaining it for others. This explains why ice is kept packed in sawdust, and the walls of a refrigerator are much like the walls of a fireless cooker.

Why Some Objects at the Same Temperature "Feel" Warmer or Cooler.—If you will lay a thermometer on a woolen blanket and on a piece of metal that have been lying side by side in the same rooms for a number of hours, you will find there is no difference in their temperature. Yet the metal feels cooler and the blanket feels warmer. If the blanket and the metal are exposed for several hours to a midsummer sun, the metal will feel hotter.

When surrounding objects are cooler than the body, good conductors feel colder than poor conductors, because the good conductors quickly convey the heat away from the body. For that reason a metal door-knob seems much colder in winter than the wood of the door itself. When objects in our surroundings are warmer than the body, good conductors feel hotter than poor conductors because the good conductors convey their heat to the body so rapidly. The metal door-knob, therefore, seems much

warmer than the door when the bright sun is shining on them both in summer.

Why do you suppose rugs feel warmer than tile, concrete, or wooden floors? Why does a woolen blanket feel warmer than a cotton or linen sheet?

Why are the handles of electric irons made of wood? What are flat-iron holders made of? Why do we use them? Why do we cover plants with paper when frost threatens? Why does linoleum feel colder than a rug? Why will the cake-pan just out of a hot oven burn your hand while the crust of the cake will not? Why are cold storage houses built with coarse sawdust packed between double walls?

Convection Currents.—Experiment 43.—Hold a piece of burning paper under a bell jar held mouth downward. (Figure 46.) Notice the air currents as indicated by the smoke. Paper soaked in a moderately strong solution of saltpeter and dried, burns with a very smoky flame.

Experiment 44.—Fill a 500 ccm. round-bottomed flask half full of water and place on a ring-stand above a Bunsen burner. (Figure 47.) Stir in a little sawdust. Some of it should fall to the bottom of the flask.

Gently heat the bottom of the flask. Notice the currents.

When the burning paper was held under the bell glass, and when the water was heated at the bottom of the flask, currents were seen to be developed. The heated and expanded air and water rose. Here again the heat was transferred by conduction, but it was helped by the upward movement of the heated water and air. These upward movements of the water and the air are known as *convection currents*.

Hot Water Is Lighter Than Cold Water.—Experiment 45.—Provide two cans of equal capacity, and of equal or approximately



FIGURE 46

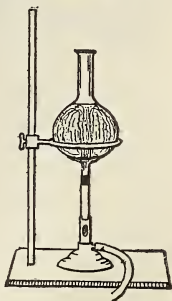


FIGURE 47

equal weight. Set one on each side of platform scales. If one is heavier than the other, sift fine sand on the platform with the lighter one until the scales balance. Now fill one can to the brim with cold water from the faucet and the other with boiling water. Which is the heavier, hot water or cold water? (Figure 48.)

It is easy to understand why cold water is heavier than hot water. If a cup full of cold water be put over a flame, it will soon "run over." The molecules of the

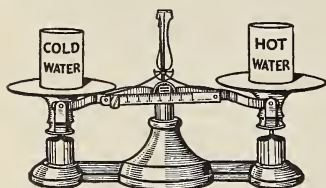


FIGURE 48

water have been driven farther and farther apart, and so the water as it gets warmer must occupy more space. Another way of saying it is that there is actually less matter (mass) in a quart cup full of boiling water than in a

quart cup full of cold water. A quart of boiling water must, therefore, be lighter than a quart of cold water. That is why, in a vessel heated from beneath, warm water rises to the top and cold water falls, thus setting up convection currents.

Whether we heat a test tube of water from above or from below, the heat is carried by conduction from one molecule to another. When we heat it from the top, the hot water remains at the top and the process of conduction downward is very slow. But when we heat it from below, the process of conduction is greatly hastened by convection currents.

Air Has Weight.—Experiment 46.—Into a five-pint bottle insert a tightly fitting rubber stopper through which a glass tube extends. To the outer end of the glass tube tightly fit a thick-walled rubber tube of sufficient length for the attachment of an air pump. Put a Hoffman's screw upon the rubber tube. (Figure 49.) See that all connections are air-tight. Weigh carefully the apparatus as thus

arranged. Now attach the rubber tube to an air pump and extract air from the bottle. When all the air that can be exhausted has been removed, close the rubber tube tightly with the Hoffman's screw and weigh again. Unclamp the Hoffman's screw and allow the air to enter the bottle. The weight should be now the same as at first.

Or, instead of weighing a bottle of air, weigh an incandescent light bulb. Make a hole in it with a blowpipe and weigh again. Is the weight now the same as before?

We have found by the previous experiment that air has weight. With the apparatus used it was impossible to tell exactly the weight of the air extracted or to determine the weight of a definite volume of the air. If we had been able to do this, we should have found that on an average day at sea level, the weight of a liter, a little more than a quart, of air is about 1.2 grams.

Hot Air Is Lighter Than Cold Air.—Air expands very much when heated, as was seen in Experiment 32. It is found that if air at freezing is heated to the temperature of boiling water, it will expand about $\frac{4}{11}$ of its volume. The force with which air expands is so great that sometimes when buildings are on fire and there is no opening for the confined air to escape, the walls are blown out or the roof blown off by the expansion of the hot air, and great injury may be done to those fighting the fire. That air expands upon being heated is readily seen when an air-filled toy balloon is brought from the cold outer air into a hot room,—the covering begins at once to tighten and the balloon to swell.



FIGURE 49

Experiment 47.—Take two open flasks of nearly the same weight and capacity and balance in as nearly a vertical position as possible at the ends of the arms of a beam balance. Bring the flame of a Bunsen burner to the upper side of the bulb of one of the flasks so that the hot air currents that are generated will have no upward push on the flask. (Figure 50.) Do not allow the hot air to get under the flask. What is the effect?

As the previous experiment shows, and as we should expect from the fact that air has been found to expand when heated, hot air is lighter than cold air. At sea level, under ordinary conditions, a liter of air at freezing temper-

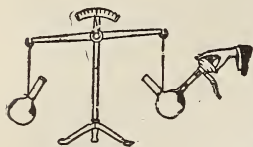


FIGURE 50

ature weighs about 1.293 grams, but at the temperature of boiling water it weighs only about .946 grams. Thus if

air is heated at any place, we should expect that there would be a rising current of hot air and a current of colder air falling and creeping in to take its place.



FIGURE 51

The efficiency of hot air and hot water systems which heat our houses is owing to convection currents. We shall find later that if it were not for convection currents there would be no winds nor ocean currents.

Radiation of Heat.—Experiment 48.—Turn on an incandescent lamp (Figure 51) and feel the glass bulb immediately. You notice the glass is still cool. Now hold your hand a little space from the bulb. Do you feel warmth coming from within?

When the lamp was made, air was taken from the bulb, and so the white-hot filament is surrounded by almost empty space (vacuum). The heat, therefore, cannot travel to the hand by conduction because there is practically no air nor other substance in contact with the filament. The hand is not warmed by convection currents because it is not held above the lamp, but rather at the side of it. The heat cannot be conducted through the air from the glass because the glass is not warm yet. Even if it could be conducted through what little air is in the bulb, then through the glass, and finally through the air intervening between your hand and the bulb, it would travel very slowly through these poor conductors. But you notice the heat *the instant the current is turned on.*

There must therefore be another method of transferring heat besides conduction and convection currents. It also appears that in this method of transferring, no material substance is necessary to convey the heat. This is shown by the fact that the hot filament is surrounded by an almost perfect vacuum. The heat of the sun travels to us with the tremendous speed of light, 186,000 miles a second, but does not warm the intervening space because there is no matter in it to be warmed. *Radiation* is the name given to this method of heat transference. If heat did not travel in this way, the earth would be uninhabitable. The conduction process is very slow when compared with radiation.

If you have ever sat on the floor in front of an open grate fire or have been one of a circle about a campfire, you have noticed that your face may become too warm while your back is chilly. A newspaper or some other object held in front of your face shields it from the heat.

You know that the air is not conducting the heat to your face. If it were, the newspaper would not shield your face because the air would conduct heat in all directions and the heated air would reach you in spite of the newspaper. You know that the heat is not being conveyed to you by convection currents, because cold air is moving *toward* the fire (that is why your back is cold) where it becomes heated and goes upward. Besides, if convection currents were carrying the heat to you, they would bring the smoke along. The heat is being radiated toward you in direct lines at terrific speed, without appreciably warming the air between you and the fire.

How Objects Are Warmed by Radiation.—A peculiar thing about heat transferred by radiation is that it travels through transparent substances like glass and air without any great heating effect on them. When this travelling

energy strikes a more or less opaque object, it is absorbed and thus heats the object. If you sit by a window through which the winter sun is shining (radiating its energy), your body is warmed by the energy absorbed, but the transparent window remains cold. The dirtier the window, the less transparent it is. It will then absorb more heat and admit less into the room.

When a shade is lowered at night, the air space between the shade and the window prevents loss of a great deal of heat by conduction. How does the shade itself help prevent loss of heat?

Experiment 49.—Procure two bright shiny tomato or coffee cans of the same size. Cover the outside of one with lampblack or dull black paint. Fill both with water freshly drawn from the faucet. Take the temperature of each with a chemical thermometer. Leave a thermometer in each can. Cover the black can with a black cover, and the shiny can with a shiny cover. Set the cans side by side inside a closed window where the sun can shine brightly on them.

Watch the temperatures of the two cans from time to time. Do you find that the water in the black can warms up more rapidly?

Some substances absorb heat that comes to them by radiation more readily than others do. If radiant heat (scientists call it radiant energy while it is traveling from one body to another) falls on a light or polished surface, much of the heat is reflected—just as light is. Light or polished surfaces, therefore, absorb radiant heat very slowly because they reflect so much of it. If radiant heat falls on a dark, rough, or unpolished surface, little of the heat is reflected. Dark, rough, or unpolished surfaces, therefore, absorb heat more rapidly and thus increase more rapidly in temperature.

Experiment 50.—Fill the two cans used in the preceding experiments with boiling water. Put a chemical thermometer in each, cover as before, and set them aside in a cool and shady place, but not in a draft. Watch the comparative temperatures from time to time. Does the water in the black can lose its heat more rapidly?

Dark, rough, or unpolished surfaces not only absorb radiant heat more readily but they radiate it more rapidly. Light or polished surfaces are slow to absorb radiant heat but when they are heated up they are just as slow to radiate their heat. An aluminum tea-kettle will stay hot longer than a black iron tea-kettle, because the bright polished aluminum does not radiate its heat so fast as the dark, unpolished iron.

We must not confuse conduction of heat with absorption of radiant heat. For example, if an aluminum tea-kettle and a black iron tea-kettle are put over flames of similar intensity, the aluminum kettle will heat up by *conduction* faster than the iron, because aluminum is a better conductor of heat than iron. But if we put the two in the sunshine, the black iron tea-kettle will *absorb radiant heat* of the sun faster than the bright polished aluminum.

Why are hot air pipes in the basement made of shiny material? Why is it wise to keep aluminum utensils for kitchen use bright and shiny? Why do we carry parasols on a hot summer's day? Why is the shady side of a street cooler than the sunny side?

SUMMARY

Heat is a form of energy which manifests itself in the motion of molecules. It seems most natural to associate the idea of heat with fire. Improvement in the art of fire making has gone hand in hand with progress of civilization. The temperature to which a substance must be brought before it will burn is called its kindling temperature. The rubbing-stick, flint and steel, and matches mark the stages of advancement in the art of fire building.

The uniting of oxygen with any element is a chemical process called combustion. Combustion may be slow as in the rusting of iron or rapid as in the burning of the fuel elements—hydrogen and carbon—found in common fuels.

All means of controlling fire are based on cutting off the oxygen supply from contact with the burning substances, or on cooling the burning material below its kindling temperature.

We have solid, liquid and gaseous fuels, but fuel elements are reduced to gaseous form in burning. It follows therefore that any fuel that is in gaseous form or that changes readily to gaseous form is ready to burn instantly when it is mixed with air. This is why great care is required in the handling of gasoline, coal gas, etc. The products of combustion of the fuel elements, hydrogen and carbon, are water and carbon dioxide. A product of incomplete combustion is carbon monoxide, a very poisonous compound. Keeping fuel elements in a furnace at or above their kindling temperature, and providing just the right amount of oxygen supply are the two problems to be solved in maintaining fire, saving fuel, and abating the smoke nuisance.

Heat causes most substances to expand; withdrawal of heat causes most substances to contract. Certain substances expand and contract uniformly through ordinary temperatures. Such substances, whether gas, metal, or liquid, may be used for measuring temperature. Devices for measuring temperature are called thermometers. The two most commonly used thermometer scales are the Centigrade and the Fahrenheit.

Temperature is not to be confused with amount of heat. It would require more heat to raise a pond of water a small fraction of one degree of temperature than to raise a kettleful many degrees. The calorie and the British Thermal Unit are the most common units for the measure of heat. It requires 143 times as much heat to change a pound of ice into a pound of water as it does to raise the temperature of a pound of water one degree Fahrenheit. It requires 972 times as much heat to change a pound of

water into steam as it does to raise the temperature of a pound of water one degree Fahrenheit.

Heat is transferred by conduction, convection currents, and radiation. In transference by conduction, each molecule "plays tag" with its neighbors passing the heat energy on to the molecule it strikes. Conduction may occur from one substance to another only when the two substances touch each other. Substances differ in their ability to conduct heat. Silver, copper, and aluminum are the best metal conductors. Still air is one of the very poorest conductors of heat, and many materials are poor conductors of heat because there are innumerable dead air spaces in their make-up.

Cold water and cold air are heavier than hot water and hot air and so if air or water be heated from below, heavy cold air or water will fall and force the hot air or water upward. This results in convection currents, which greatly hasten the heating of a body of air or of water.

Heat may travel from a body with the speed of light. Such heat is called radiant energy. It may travel through unoccupied space or pass through transparent substances without appreciably warming them. Dark or opaque substances absorb radiant heat rapidly. Light or polished surfaces absorb radiant energy slowly but reflect most of it.

QUESTIONS

What is heat?

Explain what is meant by kindling temperature.

Explain how a bird's eye match is made.

What is the main difference between a bird's eye match and a safety match?

What is fire? What two elements are known as fuel elements?

Why do not stone, sand, and iron burn?

Explain the construction of a chemical fire extinguisher.

What is spontaneous combustion?

How does a candle burn?

What is coal gas?

What cautions must be observed in the use of liquid and gaseous fuels?

How can fires be tended to do away with much of the smoke nuisance?

Explain the construction and advantages of a downdraft heating system.

What is a thermostat? On what scientific principle does it primarily depend?

How is temperature measured? Explain the differences between the Centigrade and the Fahrenheit scale.

Explain the difference between temperature and amount of heat. What is a calorie? A Btu?

What is meant by conduction of heat?

Why does a rug feel warmer than a tile floor?

Why are porous materials poor conductors of heat?

What causes convection currents in air or in water?

How are objects warmed by radiation?

CHAPTER VI

CONTROL AND USES OF HEAT IN THE HOME

*To make a happy fireside clime
To weans and wife,
That's the true pathos and sublime
Of human life.—Burns.*

Understanding of the control and uses of heat in the home is of great importance. This is true not only for the dweller in temperate and cold climates, but also for the dweller in a warm climate. For while the one is more frequently faced with the problem of increasing temperatures, the other is more often concerned with providing lower temperatures. In both cases, the principles of the transfer of heat are involved. These problems arise in connection with clothing, kitchen utensils, fireless cookers, refrigerators, heating systems, and even construction of dwellings themselves.

I. CLOTHING

Maintaining the Body's Temperature.—The body in health maintains a steady temperature of 98.6° F. In the body's self-regulation of temperature, the skin plays the most important part. If the body is too warm, it radiates a great deal of heat through the skin. If the body is normal or tends to be less than normal in temperature, it radiates less heat. Clearly the chief service of clothing is to help the body maintain itself at its normal temperature.

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Materials for Clothing.—The four most common fibers used in clothing are wool, cotton, linen, and silk. These four materials in themselves differ little in their ability to conduct heat. It is the way they may be woven that is responsible for the differences.

Projecting from every woolen fiber are little hooks or barbs. These barbs make it impossible to weave even a thin woolen garment that is not filled with air spaces. Cotton fibers have a springy twisted texture. They may be woven into cotton fleece, which conducts heat even less readily than wool, or into thin fabrics that conduct heat very readily. The disadvantage of cotton fleece over wool is that it is thick and clumsy, and tends to mat together and thus lose its air spaces.

The smooth, hard fibers of silk and linen make it possible to weave these materials into thin fabrics without air meshes. Thus they conduct heat very readily. Combinations of these fibers make garments of all degrees of "warmth." It can be seen, therefore, that it is not so much the material itself as the air trapped in the meshes of a fabric that makes one garment warmer than another.

Summer Clothing.—In summer light-colored, thin garments of silk or linen are most comfortable, because they conduct the heat from the body most readily, and their light color causes them to reflect the radiant heat of the sun instead of absorbing so much of it. Light-colored cotton fabrics are almost as effective and are much cheaper.

Winter Clothing.—In winter the meshed fabrics are warmer. Not only the air in the meshes of the garment, but also the layers of air between garments prevent the rapid conduction of heat away from the body. One wool garment is not so warm as two loose-fitting wool garments, each of half the weight of the heavy one. It

is said that over 95 per cent. of the effectiveness of feathers and fur in retarding (slowing up) the passage of heat is owing to the air spaces in their fluffy make-up.

The most common mistake in the choice of winter clothing comes of our assuming that we must be dressed as warmly as possible. Those whose work keeps them indoors or constantly going in and out should wear thinner underclothing than those who are exposed to the cold all day long. Indoor workers should provide extra outdoor protection in the form of heavier overcoats and wraps. If these heavy outer garments are removed every time the wearer comes indoors, the skin is not subjected to such extremes of temperature. For those who are driving or who are exposed to the weather on cold windy days, an outer garment of leather or rubber is most effective, because it prevents the cold wind from blowing the warm air out of the meshes of one's clothing.

II. THE KITCHEN

The Coal Range.—This seems a simple device and one that must have been known for centuries. Yet the cooking stove was practically unknown a century ago. Such stoves as were in

existence a hundred years ago were very crude affairs.

A modern kitchen range has two dampers, a directive damper and a check damper. The directive damper is so placed (Figure 52) that it may direct the draft up the flue or around the oven. The purpose of the check damper is to increase or to decrease the draft.

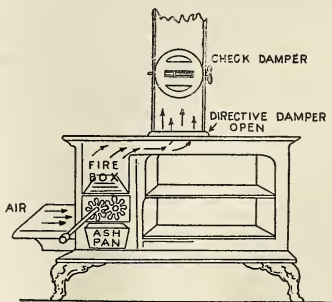


FIGURE 52.—BUILDING THE FIRE

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When a fire is built in a range, the directive damper and the check damper are both left open, in order that a strong draft may pass through the firebox and directly up the chimney. After the fire is established, the directive

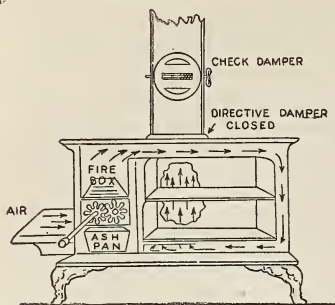


FIGURE 53.—AFTER THE FIRE IS ESTABLISHED

Heating the cooking surface and the oven.

never completely, closed, so as to retard the passage of the hot gases and to give them more time to lose their heat to the metal surfaces of the stove.

Kitchen Utensils.—The differences in the capacity of metals for heat (page 144) and in their ability to conduct heat make different metals useful for different kinds of cooking.

We have learned that aluminum and copper are better conductors of heat than iron. They also have greater capacity for heat. Thus for heating water or for boiling foods, aluminum and copper are more effective than iron.

But for preparing any foods that are to be browned, nothing excels the heavy iron, the tin-plated iron, or the enameled iron utensils. The baking of a cake or of bread or of cookies illustrates this. Iron has less capacity for heat and conducts it more slowly. Therefore the cake or

bread bakes more slowly and the top and sides are exposed to the heat long enough for crisp crusts to form. For frying, for oven roasting, and for pot roasts no utensil produces such crusty morsels as the iron.

Earthenware and enameled or "granite" ware have a great capacity for heat but conduct it more slowly than any of the metals. They are favorite utensils for the long, slow cooking or baking of food. Granite ware is most used in double boilers and baking pans; earthenware in casseroles and bean-pots.

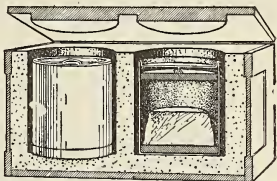
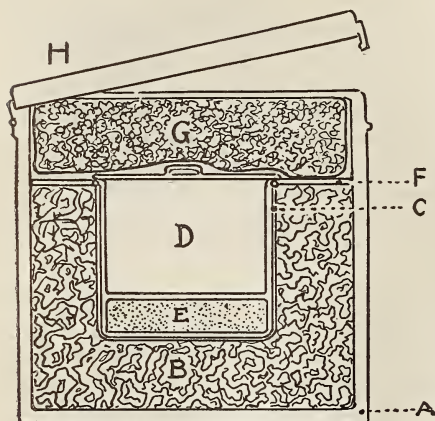


FIGURE 54.—CROSS SECTION OF FIRELESS COOKER

The Fireless Cooker.—The fireless cooker (Figure 54) is a device to save heat in cooking. It consists of two boxes, one within the other and separated from each other on all sides by a space of several inches. This space is filled with sawdust, ground cork, asbestos, or any other substance that is a poor conductor of heat. A tightly fitting cover is provided, containing similar non-conducting material. The food to be cooked is heated on the stove in a covered vessel, and this is placed within the cooker. Since the heat can escape only very slowly, the food remains at nearly the boiling point for hours, and is thus cooked. In most cookers, heated pieces of soapstone are placed above and below the dish containing the food. Soapstone has a large capacity for heat and conducts it very slowly. For that reason, it is well adapted for use in a fireless cooker, which is for long, slow boiling or baking of food.

Voluntary Project.—To make a fireless cooker. (Figure 55.) Instructions will be found in Farmers Bulletin 927 (5¢), Superintendent of Documents, Washington, D. C. Report method and results to the class.

The Refrigerator.—The fireless cooker can also be used as a crude kind of refrigerator if the food is cooled before being placed in it or if ice is placed in it with the food. When the cooker is used as a refrigerator,



Courtesy of U. S. Department of Agriculture

FIGURE 55.—LONGITUDINAL SECTION THROUGH HOME-MADE FIRELESS COOKER

Showing details of the construction: *A*, outside container (wooden box, old trunk, etc.); *B*, packing or insulating material (crumpled paper, cinders, etc.); *C*, metal lining in nest; *D*, cooking kettle; *E*, soapstone plate, or other source of heat; *F*, collar to cover insulating material; *G*, pad or cushion for top; *H*, hinged cover of box or container.

the insulated walls are very slow to conduct the heat of the atmosphere to the cold food, just as they were slow to conduct the inside heat to the cooler surrounding atmosphere. The non-conducting character of the walls protects either way. For that reason the walls of a fireless cooker are similar to those of a refrigerator.

The refrigerator illustrates the effect of temperature upon the circulation of air (Figure 56). The coldest air in the refrigerator is nearest the ice. This being heaviest falls (page 124). The farther away from the ice it gets, the warmer and therefore the lighter it becomes. The falling current of cold air pushes the warmer air up through the compartments on the opposite side and back to the ice again, thus making a continuous circulation.

Voluntary Project.—To make a cold box. Farmers Bulletin 927 (5¢). See Appendix. Report method to class.

Thermos Bottle.—The thermos bottle is a double glass bottle—one bottle within the other, and the two sealed together at the neck. (Figure 57.) Before the bottles are sealed together the air between them is removed. Heat, therefore, cannot pass from the inner bottle by conduction. To retard the passage of radiant heat, the inner walls of the vacuum space are finished with bright reflecting surfaces.

Thus if a hot liquid is put into a thermos bottle, its heat is retained. If a cold liquid is put in, heat from outside the bottle is excluded.

Why is a cork stopper used instead of a metal stopper?

III. HEATING THE HOME

Experiment 51.—Use a convection apparatus or take a tight chalk box and in two places on the top punch holes in a circle not quite as large as the bottom of a lamp chimney. Place a small lighted candle at the center of one of the circles of holes and a lamp chimney, tightly sealed to the box, about each circle. Hold a smoking piece of paper above the chimney which does not inclose the candle. (If a pane of glass is put into one of the vertical sides of the box. better

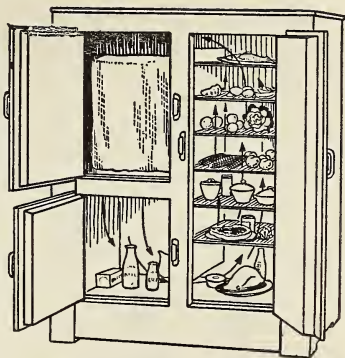


FIGURE 56.—DIAGRAM OF REFRIGERATOR SHOWING CIRCULATION OF AIR

Notice that the dainty foods are placed first in the circulatory system. Thus they are uncontaminated by the odors of strong smelling foods such as cauliflower, fish, etc. The odors from these strong smelling foods are deposited on the ice as the air goes through the ice chamber.

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observations can be made.) (Figure 58.) What happens? Put out the candle and carefully heat the chimney with a Bunsen burner.

Is there the same action as before?

Where is the air warmest in this apparatus? In what direction must this warmest air go? Why do air and smoke go down the other chimney? What are these air currents called? Why do sparks rise from a fire? What is meant by a *draft* of a stove? Why do furnaces and stoves lose so much heat up the chimney?

Relight the candle. Put your hand over the chimney containing the candle. Put your hand at the side of the chimney near the candle-flame. Do you receive more

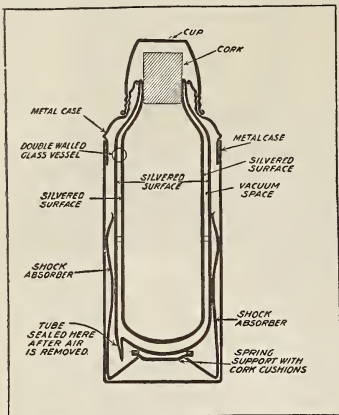


FIGURE 57.—DIAGRAM OF THERMOS BOTTLE
heat by convection currents at the top of the chimney or by conduction and radiation at the side?

The main thing to be considered in providing a means of heating the home is that we want to heat the *air* of the house. It can immediately be seen that radiation is not the best means of doing this, because radiant heat from any source of heat passes through air and glass with very little heating effect. It warms only the opaque surfaces and bodies that absorb the energy. We also know that dry, dead air is a very poor conductor of heat, and so heating by conduction alone would be a very slow process. *We must depend on convection currents* if the air in our houses is to be heated with any degree of rapidity.

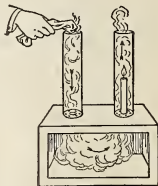


FIGURE 58

The best system of heating is the most economical, because it does the work with the least loss of heat energy. This is a most important reason for providing an efficient system. Fuel is an essential in modern life, and the nation's supply is not unlimited. Waste of fuel, therefore, not only touches our pocket-books, but also threatens the future prosperity of the nation.

Fireplaces and Stoves.—The most cheerful contrivance for heating a room is the open fireplace, but it is also the least effective. As was shown on page 125, heat from a fireplace is not transferred to the room by conduction. The warm convection currents go up the chimney. Heat travels into the room almost wholly by radiation. Thus the radiant energy of the open fire passes *through* the air and heats only walls and opaque objects it strikes. These in turn conduct some heat to the air. A large per cent of the radiant energy from the fire travels straight through the air and out the glazed windows.

Stoves are more effective, because they heat the air by conduction and set up convection currents. It is estimated, however, that from 40 per cent to 60 per cent of the heat of a stove is radiated through the windows and is lost to the household.

The *jacketed stove* has a great advantage over the ordinary stove. (Figure 59.) Much of the radiant heat is saved by this device. Heat radiating from the stove is absorbed by the dark inner surface of the metal jacket. Convection currents passing between this jacket and the stove receive heat by conduction from the metal surfaces and carry it to other parts of the room.

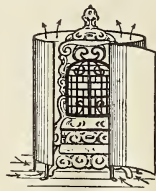


FIGURE 59.—JACKETED STOVE

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The Hot Air Furnace.—For cottages and small houses the hot air furnace is the most effective and the most economical way of heating. As has been said, the problem in all heating devices is to prevent loss of heat by radiation. The hot air furnace (Figure 60) is surrounded by a metal jacket. The space between this jacket and the furnace is the hot air chamber. As in the case of the

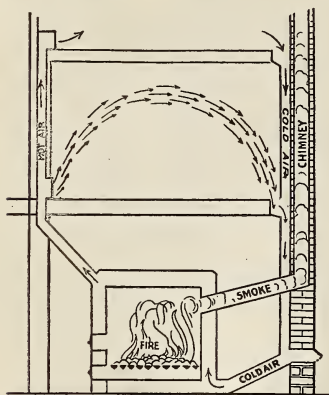


FIGURE 60.—DIAGRAM OF HOT AIR SYSTEM OF HEATING

jacketed stove, the inside of the jacket is dark so as to favor the absorption of heat. The outside of the jacket is generally galvanized; that is, brightly coated with zinc, to retard radiation.

The air circulating between hot metal surfaces is heated by conduction and passes up the warm air "ducts" to the rooms. This light warm air rises to the ceiling while the heavier cold air falls to the floor and passes down

the cold air ducts. This cold air enters the lower part of the hot air chamber, is heated and passes out of the upper part of the enclosure into the warm air ducts again. Thus a continuous circulation of air is kept up.

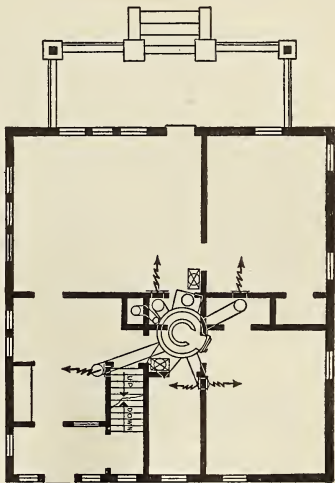
This is known as the pipe furnace system. It circulates the air inside the house. In modern practice, heating outside air is thought unnecessary and wasteful of fuel. In the average home, where the hot air furnace is circulating the air of the house the entrance of fresh air around doors and windows is sufficient for ordinary requirements.

The great objection to the hot air system, unless it is

steadily watched, is the unevenness of heat. The moment the fire begins to dwindle, the house begins to cool. On the other hand a roaring fire may furnish too much heat for a while. Electric devices controlled by thermostats steady the operation of a furnace by automatically opening and closing drafts as the temperature of the house varies. Thus the temperature of the house is governed by direct control of the amount of fuel burned. It is pretty generally agreed that a reliable thermostat will pay for itself not only in convenience but also in the actual saving of fuel.

The Hot Water System of heating.—Experiment 52.—(Teacher's Demonstration). — Prepare apparatus as indicated in Figure 61. Into an 8 x 1 inch test tube *B* (the boiler), insert a two-hole rubber stopper. The radiator *R* is the upper portion of a student's lamp chimney. Fit the lower end of it with a two-hole stopper and the upper end with a one-hole stopper.

Connect the boiler and the radiator with glass tubing as indicated in Figure 61. The Tube *H* should reach from just inside the rubber stopper of *B* almost to the top of *R*. The tube *C* should reach from the bottom of *B* to the Y-tube at *Y*. By means of rubber tubing connect one arm of the Y-tube with a small piece of glass tubing that



Courtesy Mueller Furnace Company
 DIAGRAM SHOWING PROPER PLACEMENT OF
 HOT AIR FURNACE

The hot air furnace should be placed as near the center of a basement as possible so that there will be no long horizontal pipes running out to distant rooms. Convection currents to be effective must rise almost immediately from their source.

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extends through a hole of the stopper to the bottom of *R*. Connect the other arm as indicated with the funnel at *F*. In the one-hole stopper at the top of *R* insert a short piece of glass tubing, and connect it by means of rubber tubing with a valve *V*.

Pour water into the funnel. If all the connections in your apparatus are tight, you will have to open the valve *V* before the apparatus will fill up. Why? When the water reaches the top of *R* close the valve.

Heat the boiler *B*. If air bubbles collect at the top of *R*, open the valve and let them escape. Heating water drives air out of it. We shall learn why in another chapter.

Notice that the tube *H* becomes warm before *C*. Water heated by the flame under the "boiler" rises to the top of *B* and up the tube *H* to the top of *R*, the "radiator." Where does the heavier cold water at the bottom of the radiator go? Explain how circulation is kept up as long as there is heat under the boiler.

As the water increases in temperature, watch it rise in the funnel. Why does it rise? If it were not for this "*expansion tank*," what would happen to the apparatus as the water in the system expands?

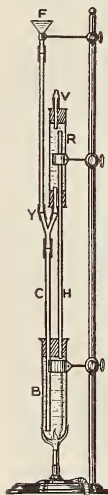


FIGURE 61

This illustrates the working of a hot water system of heating (Figure 62). We have learned that water has a great capacity for heat (page 114). Hot water from the boiler rises to the radiator where some of its heat is given up to the colder iron of the radiator. It passes through the iron by conduction. The iron conducts the heat to the surrounding air, and thus sets up convection currents which convey the heat throughout the room. Of course a great deal of heat passes from each radiator by radiation. Much of this goes through the air and out the windows and thus is lost.

It costs more to install a hot water system and takes more fuel to operate it than to operate a hot air system properly. On the other hand, the hot water system has the advantage of furnishing a steadier source of heat. Water

heats up slowly and so a house cannot be warmed so quickly with hot water as with a hot air furnace. But water does not give up all its heat quickly. The metal surfaces of the hot air furnace have not much heat stored up in them (page 140), and so when the fire dwindles, the metal soon loses most of its heat. But the water in a hot water system continues to circulate and to give off heat slowly even when the fire under the boiler begins to get low.

When a hot water system is not in operation in cold weather, it should be drained to prevent the water from freezing and bursting the pipes. For the same reason, in very cold weather, a radiator should never be "turned off" and thus cut off from a warm water supply.

Steam Heating.—**Experiment 53.** Boil water in a flask or tea kettle. Invert a cold, dry aluminum pan over the cloud of steam rising from the boiling water, and hold it there for a minute or two. Feel the outside of the bottom of the pan. Is it hot? Look at the inside of it. Has moisture gathered there?

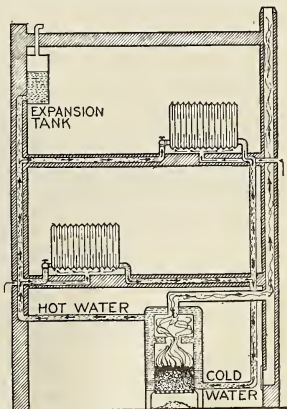


FIGURE 62.—DIAGRAM OF HOT WATER SYSTEM OF HEATING

What you see illustrates one of the main principles of steam heating. (Figure 63). We have learned that a pound of water in changing to steam takes up 972 times as much heat as it does when it increases one degree of temperature (page 116). When the steam condenses in the cool radiator, as it did on the cold pan, it gives all this heat out again. This explains why a steam heating plant may be made to furnish more heat than a hot water

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system. Because of this, however, a steam heating plant is not so easily regulated for mild weather.

When water is changed to steam, it increases in volume more than 1700 times. This expanding steam must find room for itself and so it fills the pipes and radiators. As

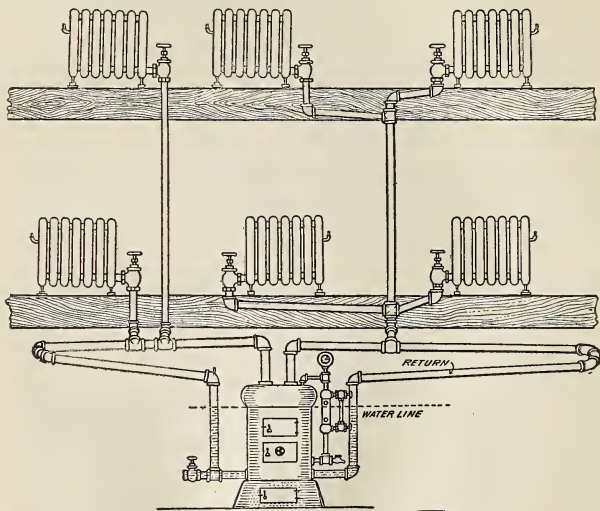


FIGURE 63.—A STEAM HEAT PLANT

Notice that all of the pipes are slanted downward so that the water of condensation may flow back to the lower part of the boiler. In a steam boiler water surrounds the entire firebox so as to conserve heat.

it comes into the radiator, it drives the air out of the vents. When the fire is low and steam ceases to form, air returns by these vents and fills the radiators. As the steam condenses into water, this water flows down to the boiler by the return pipes. These return pipes are also provided with air vents near the boiler.

A steam plant uses more coal than a hot water system,

because the water in a steam boiler must be kept at a boiling temperature. If the fire under a steam boiler begins to get low, the water falls below the boiling point, and the supply of steam is cut off quickly. It is not so steady, therefore, as the hot water system. Like the hot water radiators, the steam radiators also lose heat by radiation.

For large buildings, steam heating is the only efficient system.

A great deal of heat is lost from the pipes conveying hot water or steam to the radiators. What is generally used to cover these pipes and the boilers themselves to prevent this loss of heat?

Soot is one of the poorest conductors of heat. What must therefore be done regularly to the surfaces exposed to smoke?

Insulating the Walls of a Home.
—Stone and brick are poor conductors of heat, and so well-constructed stone and brick houses may be kept warm in winter and cool in summer. In the building of a frame house, care should be taken to insulate the walls against the transfer of heat.

To one side of the uprights of a frame wall are attached laths and plaster (both poor conductors of heat). (Figure 64.) To the other side is nailed the sheathing. Between these are air spaces extending from upright to upright. These air spaces should be closed as tightly as possible both above and below so as to prevent circulation. Why? Modern builders cover the sheathing with heavy paper or felt. This not only adds another thickness of

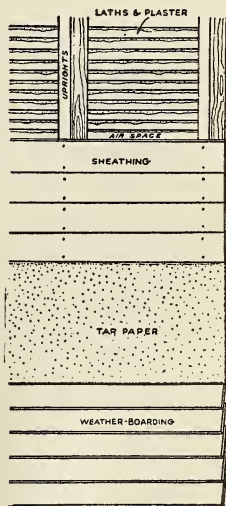


FIGURE 64.—INSULATED WALL OF A FRAME HOUSE

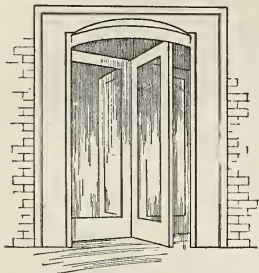
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non-conducting material but further helps to deaden the air spaces in the walls.

A well-laid floor has the spaces between beams filled with porous material, which not only serves to keep the floors warmer but also to deaden sound.

It is not generally recognized that an electric fan may

be made just as useful in winter as in summer. The warm air in a room tends to rise to the upper part of the room. A fan placed as near the ceiling as possible will force this warm air down to a lower level, and in this way make all parts of the room more nearly uniform in temperature. This often proves an effective remedy for cold floors.



REVOLVING DOOR

Device for conserving heat and preventing draft.

What advantage has a house with an attic over a house with a flat roof both in summer and in winter?

Ventilation.—The movement of air caused by its heating and cooling provides a means for ventilating rooms and buildings in winter. In warm weather we do not have to be persuaded to keep our windows open; but when winter comes, many people become careless about ventilating their houses. Health requires that a person have pure, normally moist air to breathe. Sleeping rooms as well as living rooms must be constantly supplied with outdoor air. The old notion that night air is harmful is contrary to the truth. Fresh air day and night is essential to the maintenance of health.

Several ways have been devised for ventilating large buildings and for maintaining proper air conditions, but these require mechanical means for driving or for draw-

ing the air into the building, and are not suitable for dwellings.

Houses heated by hot air furnaces which circulate the air of the house (Figure 60) need only provision for the exit of hot, stale air. An open grate or fireplace in which there is a fire, or a window in each room opened slightly at the top, will accomplish this.

Most houses cannot be ventilated except through the windows and doors. It is most important to learn how this may be done effectively.

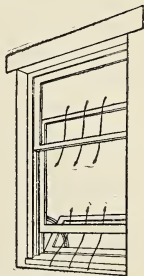


FIGURE 65:—COMMERCIAL VENTILATING DEVICE

Showing direction of air currents.

Voluntary Project.—To make ventilating devices for the home. 1. A board that fits exactly under the lower sash. 2. A board fitted to the sill to deflect the current of cold air. Figure 65 shows a commercial device of this sort. 3. A cloth screen (framed like a wire screen) to ventilate a sleeping room in severe weather. Explain how the device you make serves its purpose.

SUMMARY

Control and uses of heat in the home involve chiefly the principles of transference of heat. Problems of the household arise in connection with clothing, kitchen utensils, fireless cookers, refrigerators, heating systems and even construction of dwellings themselves.

The purpose of clothing is to aid the body in its self-regulation of temperature. Summer clothing should therefore be of materials that readily conduct heat from the body. Winter clothing should be made of fabrics so woven that dead air is trapped in innumerable meshes. For those who are exposed all day to the rigors of severe

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winter, heavier underclothing is necessary than for those who work indoors.

The control of convection currents by means of the check damper and the directive damper is the chief problem in connection with the kitchen range. Different metals are adapted to different kinds of cooking utensils, dependent upon the ability of each metal to conduct heat. In the fireless cooker, the walls are so constructed as to retard the radiation or conduction of heat from the interior. The walls of the refrigerator are constructed in much the same way as those of a fireless cooker, the purpose of the construction in this case being to retard the conduction of heat from the outside to the interior. The thermos bottle is constructed with a vacuum space to retard the conduction of heat and with bright inner walls to retard radiation.

In the heating of the home, the best system is the one which makes available the largest amount of heat per pound of fuel. Heating of the air of a house is the main thing to be considered. We must therefore depend on convection currents for efficient house-heating. Fireplaces are the least efficient means of heating because most of the convection currents go up the chimney and most of the rest of the heat is radiated out the glazed windows. Stoves are superior to fireplaces because they set up convection currents, but much of the stove heat is lost by radiation. Jacketed stoves prevent much of the loss of heat by radiation.

The well-regulated hot air furnace is the most efficient means of heating small houses because more of the heat is used to set up convection currents and less is lost by radiation. The hot water system is more expensive to install and to operate than a hot air system, but it furnishes a steadier supply of heat. The steam plant is the most expensive of the three, but it is the only efficient system for large buildings.

Brick and stone are the best materials of which to build the walls of a house because they are the best insulators against the transfer of heat. In the building of a frame house, it is necessary to provide for dead air spaces in the walls and use as many thicknesses as possible of non-conducting materials. A well-insulated wall helps to keep a house warm in winter and cool in summer.

Ventilation of a home is necessary to health. Most houses cannot be ventilated except through windows and doors. The main problem is to furnish sufficient fresh air without subjecting ourselves to drafts.

QUESTIONS

What are the best materials for summer clothing? Why?

Why is wool better adapted than silk, cotton, or linen to the making of winter clothing?

How should the indoor worker plan to dress in winter? The outdoor worker?

What is the purpose of the directive damper in a cook stove?

Why are heavy iron kitchen utensils better for baking bread and cakes?

Explain the construction of a fireless cooker.

Explain the construction of a refrigerator and the circulation of air in it.

Why does a thermos bottle serve equally well to keep hot liquids hot and cold liquids cold?

Why is a stove more effective than a fireplace for heating a room?

Why is a jacketed stove more effective than an ordinary stove?

Explain the operation of a hot air furnace. What are its advantages and disadvantages?

Explain the operation of a hot water system of heating. What are its advantages and disadvantages?

Explain the operation of a steam heating plant. What are its advantages and disadvantages?

Why is a wall that is well insulated against heat, of equal advantage summer and winter?

Tell why ventilation is important. Describe a simple way to ventilate a room without having the discomfort of drafts.

CHAPTER VII

HEAT AND THE EARTH'S CRUST

Let the great world spin forever down the ringing grooves of change.—
Tennyson.

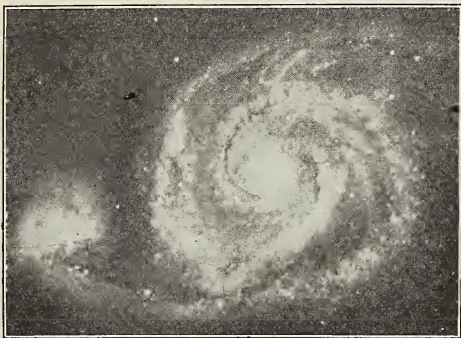
Careful studies of the soils and of the rocky formations of the earth have revealed many of the changes through which this old earth has come in millions of years. It is certain that heat has had a very important part in molding the face of the earth.

A Theory of the Earth's Beginnings.—Of the earth's beginnings we *know absolutely nothing* in a scientific way. There are several interesting *theories* of how the solar system came into existence, but none of them is wholly accepted by scientists.

The interesting theory of two American scientists, Professors Chamberlin and Moulton, takes us back ages and ages to a time when all the matter in the entire solar system is supposed to have existed simply as a sun. As this parent sun traveled through space hundreds of millions of years ago, another sun is supposed to have passed near it. This passing sun acted through gravitation on the fiery liquid materials of our sun very much as the moon acts upon our ocean waters.

The passing sun pulled from our sun a great stream or tide of matter which started in knots and clouds in the direction of the visitor's flight. It also pulled the entire sun itself so violently that an arm of matter formed on the opposite side just as tides form on the side of the earth opposite the moon.

But while this matter pulled by gravitation from our sun trailed the visitor for millions of miles, it did not get beyond the control of the parent sun. By inertia the tendency of this loosened matter was to fly away in a straight line, but it was held in check by the attraction of



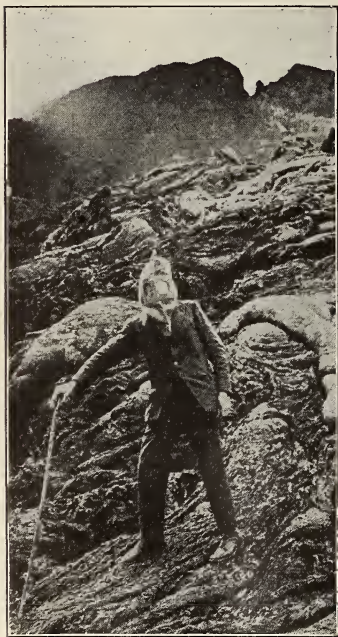
SPIRAL NEBULA

The condition of one of the faint stars as revealed by the telescope. It is millions of miles in extent. Many scientists believe that the solar system was in such a nebular state as this ages ago; and that such a nebula as this may develop into another solar system after millions of years.

the parent sun. And so all this loosened matter began its age-long circuit of our sun (page 15).

The picture on this page represents such a *nebula* or cloud of matter, now visible through the telescope. It is believed by some scientists that the central part of this nebula will some day be a spherical sun, and the knots will be planets. Little by little through millions of years the finely divided material will collect on the knots or be attracted into the central mass of the sun and another solar system will be formed. In this way, it is believed our solar system was born.

A Molten Sphere.—Whatever theory scientists may hold as to the origin of the earth, it is generally believed that the matter of the earth was once in a nebular or gaseous state—"The earth was without form and void." Uncounted ages afterward it came into a molten or exceedingly hot liquid condition.



International Photo

LAVA FROM VESUVIUS

It has hardened but has not completely cooled.

Notice the mask this investigator wears to protect his face and eyes from the heat.

As this molten sphere lost its heat, a crust began to form on its surface. This first crust must have been an unstable covering, seething and swaying like ocean billows over the molten interior. It is probable that frequent boilings through the crust brought the lighter materials up to cool as the beginnings of continents.

As the molten interior of the earth cooled and shrank, the areas of heaviest rock in the solid crust sank to rest on the shrinking core, and buckled the lighter materials still higher. The wrinkling of the skin of a baked apple, as the interior of the apple cools, gives us a faint notion of what has been happening to the crust of the earth through the ages.

Interchange of Sea and Land.—There are many reasons for believing that in the age-long course of crumpling and shrinking, dry lands have disappeared under ocean waters, and ocean floors have been elevated into dry land.

A gradually deepening ocean floor, called the *continental*



TEMPLE OF JUPITER NEAR NAPLES

Although it can be proved that this coast has been elevated and depressed several times, so gradual has been the movement, that the pillars have not been overturned.

shelf, surrounds each continent. When this floor has reached the depth of about 600 feet, the gradual slant suddenly changes into a quick descent to the *depths of the ocean*, two or three miles. There are many reasons for believing that the depths of the sea have never been elevated into dry land, but that what is now deep ocean has throughout all time been deep ocean.

It is also believed that while almost all portions of the present continents have been at times above, at times below, the level of the ocean, the present great land

masses have remained on the whole the same since continents and ocean basins first formed.

It is impossible for us to conceive the eons of time that passed while the earth's exterior was cooling and changing, and coming into the condition in which we know it. Geologists think in tens and hundreds of thousands of years. The mountains that we see and even the continents we live on are the product of very recent changes, as

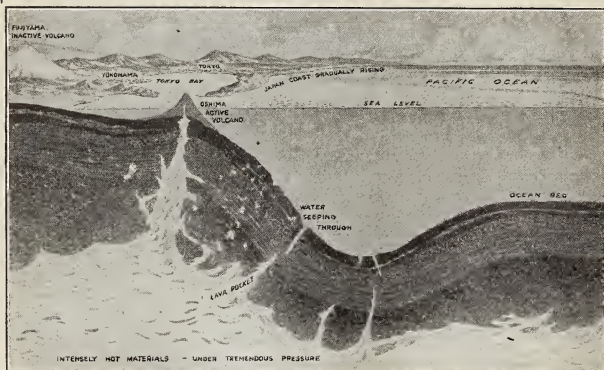


FIGURE 66.—A THEORY OF EARTHQUAKES PICTURED—DIAGRAM I

This shows the conditions which according to the theory explained in the accompanying text lead eventually to a violent earthquake.

geologists measure time, in the unimaginably long ages that reach back to the first gathering together of matter forming the earth.

Within the Earth's Crust.—Whenever borings have been made into the interior of the earth it has been found, after a depth has been reached where there is no effect from the heat of the sun, that the temperature rises as the depth increases.

The interior of the earth, it is reckoned, attains a heat

of thousands of degrees Centigrade. But the tremendous pressure of miles of overlying materials keeps the molecules packed so tightly together that they probably cannot expand into liquid form.

Mountain Building.—Mountain ranges have probably been formed by the crumpling and pinching up of the crust of the earth. Most of these mountain chains are

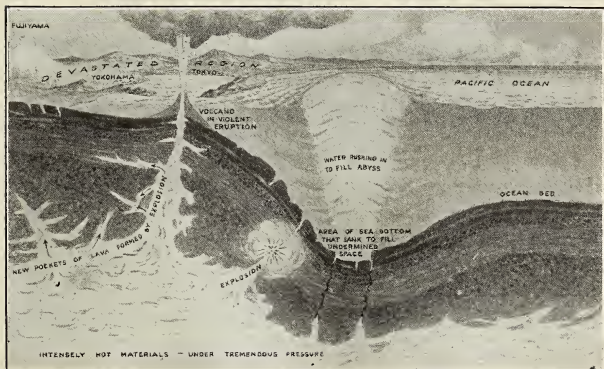


FIGURE 67.—A THEORY OF EARTHQUAKES PICTURED—DIAGRAM II

Immediate results of the explosion which according to the theory explained produces a violent earthquake.

on the edges of continents. Those that are not are thought to have fringed the edge of the continent when they were formed. We shall see in another chapter that rocks in these mountain chains indicate that the mountainous area was ages ago under the sea. These submerged areas were at the edges of the young continents.

As the interior of the earth cooled and shrank, it seems probable that the heavier crust forming the bottom of the sea and weighted by the overlying waters should have settled and crumpled the lighter crust near the continents

into ridges or mountain chains. Thus the Alps once formed the level bed of a sea. It is supposed that the area was gradually buckled into mountain ranges by the sinking of land that once stood above the level of the Mediterranean Sea.

Earthquakes and Volcanoes.—There is every reason to believe that the interior of the earth is still cooling and contracting. Since the crust is already cooled, it has ceased to contract. The cooling of the earth's interior is so slow that the folding usually disturbs the surface but little at a time. In recent hundreds of thousands of years, therefore, geological changes have usually taken place very gradually. These slow changes are still continuing, and the surface of the earth is being constantly modified.

Sometimes the strain of folding has resulted in clean breaks that cleave the rocky crust down to great depths. These breaks are known as *faults*. When next this portion of the earth's crust adjusts itself to the changing conditions underneath, one wall of this fault may slip a fraction of an inch against the other. This grinding of these gigantic walls together manifests itself in an earthquake.

Experiment 54.—Put a marble on the upturned end of an empty wooden box. Give the box end a sharp rap with a heavy hammer. Does the marble bounce an inch or so up from the box?

This experiment illustrates why the slipping of the rocky crust only a fraction of an inch may cause such tremendous vibrations as to wreck buildings. It is the suddenness and violence of the slip that creates such havoc.

There is no certainty as to the exact causes of violent earthquakes and volcanoes. Scientists hold various theories but no theory is to be accepted as a statement of settled facts. According to one of the most interesting explanations offered, violent earthquakes and volcanoes result from the seepage of ocean water through miles of the

earth's crust to terrifically hot layers underneath. Destructive earthquakes and volcanoes, with the rarest exception, occur on the rims of oceans. These disturbances, it is claimed, represent continent and mountain building now going on. The greatest mountain chains surround the greatest and deepest of the oceans, the Pacific. Surrounding the Pacific too is the greatest area of volcanic and earthquake disturbance.

It may be that not many miles within the crust of the earth are pockets of molten lava. Perhaps the pressure on

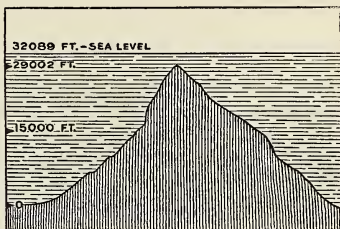


FIGURE 68.—GREATEST OCEAN DEPTH COMPARED WITH GREATEST MOUNTAIN HEIGHT

these pockets is so great that the lava cannot be in a molten state. But the material is so hot that it will instantly return to a liquid state the moment any of the overlying pressure is released. Water is constantly seeping through the ocean floor to these hot layers beneath. After this seeping has gone on for a good while, the pressure of the lava swollen by steam becomes so terrific that the material must find more room; that is, explode.

To understand what then happens we must know something of the weight of the overlying waters and the bending of the rocky layers under this weight. The area of the Pacific Ocean is greater than that of all the land in the world and the volume of its waters is six times that of all the land above sea-level. This tremendous body of water presses on the bottom of the ocean with an average weight of *three tons to the square inch*. In the neighborhood of the Philippine Islands and the Island of Guam the water presses on the ocean bed with a weight of more than seven tons to the square inch. (Figure 68.) In geological times the

weight of the ocean waters compressing the rocky layers underneath has deepened the ocean bed nearly one thousand feet. Thus the rocky layers of the earth's crust have been bent downward at the ocean's edge to form the slanting rim of the ocean's bed.

Now when the lava swollen by the steam of the seeping



International Photo

RETAIL DISTRICT OF TOKIO, JAPAN, AFTER THE TERRIBLE EARTHQUAKE OF 1923
Only a few buildings of the most modern steel and concrete construction survived the disaster.

waters begins to move, it moves in the direction where the least resistance is offered. Thus it rolls between the rocky layers, from under the terrific weight of the ocean up under the continent's edge. The rolling of this lava under the continent's edge shakes the overlying crust and produces earthquakes. The landward movement of this lava is thus a part of the slow process of continent and mountain building.

Sometimes this incoming lava, saturated with steam, escapes through "safety-valves," which are our volcanoes. The periods of quiet between earthquake disturbances and between outbursts of volcanic activity are periods during which water is again slowly seeping through to the hot layers and expanding the hot materials to a point where they must shake the crust and roll landward again.



VESUVIUS IN ACTION

The city of Naples in the foreground.

The transfer of lava from under the sea leaves a portion of the floor of the sea undermined. Thus the sea bottom over an area as large as a county may sink to fill the undermined space. And so the land is raised as the sea is deepened.

Tidal Waves.—The dropping of a large area of sea bottom explains the *tidal wave*. To fill the new abyss, the waters come pouring in from every side. These currents meet in a gigantic mound of water over the newly

formed depression, and then roll into shore in the form of a tidal wave. This accounts for the fact that in a tidal wave the water first recedes from the shore and then washes back with tremendous force and often to a great height. A tidal wave followed the Japanese earthquake



RESULTS OF THE TIDAL WAVE IN TOKIO BAY

P. and A. Photo

This picture was taken immediately following the receding of the wave.

in the fall of 1923. The tidal wave following the famous Lisbon earthquake of 1755 rose in places to a height of 60 feet.

SUMMARY

There is a theory that the solar system originated through gravitation and inertia when our parent sun passed near another sun millions and millions of years ago. Whatever the origin of the solar system, it is generally believed that the matter of the earth was once

in a nebular or gaseous state and that from this it came, uncounted ages afterward, into a molten condition.

As the crust cooled and shrank, the surface became uneven. Heavier materials sank to rest in the shrinking core and buckled the lighter materials upward. Thus the continents and ocean beds may have originated. In the age-long course of crumpling and shrinking, which is still going on, dry lands have disappeared under ocean waters and ocean floors have been elevated into dry land again and again.

Borings into the earth's crust show that the core of the earth is still very hot. The cooling of this core and the adjustment of the overlying crust to the shrinking core is responsible for earthquakes. One modern scientist holds the theory that destructive earthquakes and volcanoes are caused by the seeping of ocean waters through to hot layers miles within the crust. Resulting explosions are responsible for volcanoes, earthquakes, and tidal waves.

QUESTIONS

Explain the theory of Professors Chamberlin and Moulton as to the beginnings of the solar system.

What has caused the interchange of sea and land and the formation of mountain ranges?

What causes earthquakes?

Explain the theory of violent earthquakes and volcanoes that is described in this chapter.

According to this theory, how are tidal waves caused?

CHAPTER VIII

THE ATMOSPHERE AND ITS SERVICE TO MAN

A man's best things are nearest him.—Lord Houghton..

We have learned something of the universe and of its make-up. We have found what “makes things go.” We have studied heat, the form of energy most commonly employed by man. We have learned that this same form of energy, with the aid of gravitation, has been responsible for heaping up the continents and hollowing out the seas. We now come to the *most important thing, or substance*, in our immediate surroundings.

Air is a constant essential. Other things are needed for the support of life, but air is the only thing that must be on hand in unfailing supply minute after minute of our existence. A man in normal health could lie abed more than a month without food, and could live without water for about four days. But he would be dead in four minutes if deprived of air. Without air there could be no animal nor plant life, no fires, no winds, no rains, no running streams—nothing but lifeless, desert lands and oceans unruffled except by the rolling tides.

The Origin of the Atmosphere.—When the earth cooled from its original intensely hot condition, the substances which did not chemically combine to form liquids and solids, or which required a very low temperature for their consolidation, were left still in the gaseous state outside the solid crust. This gaseous envelope, composed of these

substances surrounding the earth, we call the *atmosphere*. Some of these gases are inert; that is, they do not readily form chemical combinations with other substances. Others have formed extensive combinations, but they existed in such large quantities that they were not thereby exhausted.

I. COMPOSITION OF THE AIR

Experiment 55.—(Teacher's Demonstration.)—Having rounded out a cavity in a small flat cork, cover the cavity and surface around it with a thin layer of plaster of Paris. After the plaster has set and become thoroughly dry, float the cork on a dish of water with the cavity side up. Place a piece of phosphorus as large as a pea in the cavity and carefully light it. (Figure 69.) (Great care must be taken in handling phosphorus, as it ignites at a low temperature and burns with great fierceness. It must always be cut and handled under water.)



FIGURE 69

As soon as the phosphorus is lighted, cover it with a wide-mouthed bottle. Be sure that the mouth of the bottle is kept slightly under water. Does the water rise in the bottle? The phosphorus soon ceases to burn.

Can you tell why the water rose in the bottle as long as the burning continued? Does the remaining gas burn? Does it support combustion? Does it differ in appearance from air?

N.B. Be careful to put the cork on which the phosphorus was burned in a place where it can not cause a fire.

The phosphorus burned under the bottle as long as there was a supply of oxygen to combine with it. White fumes were formed as a result of this chemical combination, but these were soon taken up by the water.

The gas left in the bottle fills almost four-fifths of the space occupied by the air before it lost its oxygen. It is clear then that oxygen forms about one-fifth of the at-

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mosphere. The gas that remains in the bottle is almost all *nitrogen*. It is transparent, colorless, tasteless, and odorless, as is the air itself.

Although the air appears to be a simple gas and was so considered until the end of the eighteenth century, it has been shown to be a mixture of several different colorless gases. One of these, oxygen, supports combustion, as we have already learned; another, nitrogen, neither burns nor supports combustion. These two gases make up by far the greater part of the air about us, and occur in the proportion of about one part of oxygen to four parts of nitrogen. Carbon dioxide is also found in the air in the proportion of about 3 parts to 10,000. There are in addition very small quantities of several other gases, but these are not of sufficient importance to be studied here. Besides the gases, the air contains other matter, such as water vapor, dust particles, and microbes.

Almost all of us have had occasion to observe that if there is a slight leak of gas from the gas stove in the kitchen, the "smell of gas" will permeate the whole house. It makes no difference whether there are currents of air to carry the gas or not. The molecules of gases, whether heavy or light, move freely among themselves; and so gases mix readily with each other, or *diffuse*. As a rule, therefore, the proportion of oxygen, nitrogen, carbon dioxide, and other gases is the same for all places on the surface of the earth.

Oxygen is the most important part of the air to animals, for without it they could not live. They breathe in oxygen, and breathe out carbon dioxide. All the heat and energy animals have is due to their power of combining oxygen with carbon. Plants also have need of oxygen, but to a smaller degree than animals.

The nitrogen is needed to dilute the oxygen. If oxygen were undiluted, animals could not live; and, as we have

already learned, a fire once started would burn up iron as readily as it now does wood.

II. MOISTURE IN THE AIR

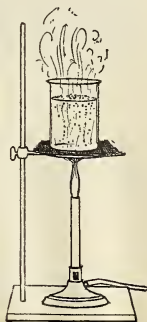
Evaporation.—The atmosphere at all times and under all conditions contains some moisture. In the air of even the driest desert there is some water vapor. Plants and animals both need it. Were it not for the moisture in the air there would be no rain; and without rain no land life could exist. Thus the air, which contains oxygen and water vapor for both plants and animals, carbon dioxide for plants, and nitrogen to dilute the oxygen, is one of the most important life factors of the earth.

Experiment 56.—Carefully weigh a dish of water and put it in a convenient place where there is free access of air. After some hours weigh it again. What causes the change of weight? Try this experiment with a test tube, a watch crystal, and a wide-mouthed beaker, under various conditions and in various places.

When water is exposed to the air, it gradually disappears into the surrounding atmosphere. This process is called *evaporation*. Evaporation takes place only from the surface of a body of water. It may occur at any temperature, but since heat is absorbed in the process of evaporation (page 117), the more heat there is available, the more rapid will be the evaporation.

Evaporation must not be confused with boiling. Heat is absorbed in both processes; but boiling takes place only at a *definite* temperature and goes on *inside* the liquid.

If the water surface is large and the temperature high, there is a large amount of evaporation and the water rapidly rises in-



BOILING ACCOMPANIED BY
RAPID EVAPORATION

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to the air. In the tropics the evaporation from the water surface amounts to perhaps eight feet per year. This means that the energy of the sun evaporates about five hundred pounds of water from every square foot of the surface every year. In the polar latitudes the amount of evaporation is perhaps a tenth of that in the tropics.

Warm Air Can Hold More Moisture Than Cold Air.—

Experiment 57.—(Teacher's Demonstration.)—Into a liter flask pour a small amount of water. Shake the water around well until the inside of the flask is covered with a thin film of moisture. Pour out the remainder. Warm the flask gently and gradually until the moisture disappears from the inside of the flask, and the flask appears to be perfectly dry. Immediately cork the flask tightly, and allow it to cool. Does the moisture reappear on the inner walls of the flask?

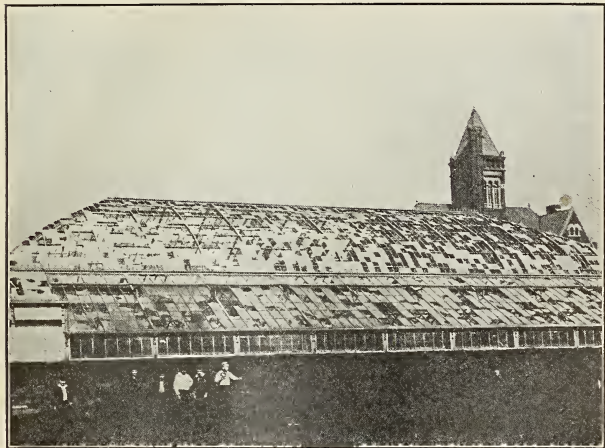
The flask appears dry when the air in it is warm, but is again lined with a film of moisture when the air gets cool. Apparently the air when it was warmed took up the moisture, and when it was cooled deposited it again.

When we wish to dry clothes, we place them in a warm ventilated room or in the sunshine. Soon we find that the water has left the clothes. It must have gone into the air. It would thus appear that when the temperature of the air is raised, it has the capacity of taking up more moisture than when it was cooler.

Air May Become Saturated with Moisture; Condensation.—**Experiment 58.**—Procure two bright tin dishes or glass beakers. Fill one with ice water and the other with water of a temperature equal to, or higher than, that of the room. Carefully wipe the outsides of both vessels and allow them to stand for some time in the warm room.

Does moisture collect on the outside of either vessel? Does the dew on the outside of the cold vessel come through the walls of the vessel from the inside? If so, would not the hot water have come through the walls of the other vessel too? Where do you conclude the water must have come from?

Rains are evidence of the fact that air may reach a point where it will hold no more moisture. When air is holding all the moisture it will contain, it is said to be *saturated*. The higher the temperature of the air, the greater the amount of moisture that is required to saturate it. For example, a cubic foot of air at 50° F. will hold



Courtesy U. S. Weather Bureau

DAMAGE DONE BY A HAILSTORM

Conservatory at Allegheny, Pa., after the memorable hailstorm of May 20, 1893.

slightly more than 4 grains of water vapor; at 60° F. it will hold $5\frac{3}{4}$ grains; at 70° F., it will hold almost 8 grains; and at 80° F. it will hold about 11 grains.

Now suppose that the air of the room in which you performed this experiment is at a temperature of 80° F., and contains 5 grains of moisture per cubic foot. If the temperature of the air is suddenly reduced to 50° F., the air will have to deposit some of its moisture because air at 50° F. will hold only about 4 grains of water vapor per

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cubic foot. The air around the ice water vessel was reduced to so low a temperature that it could not carry all the water it had carried when it was warmer. The extra moisture therefore *condensed* on the cold vessel.

Dew Point.—Experiment 59.—(Teacher's Demonstration.)—Partly fill a dish or beaker like that in the previous experiment with water having a temperature a little higher than that of the room. Gradually add pieces of ice, continually stirring with a chemical thermometer. Note the temperature at which a mist begins to appear upon the outside of the dish. When the mist has appeared, add no more ice but stir until the mist begins to disappear. Note this temperature. Take the average of these two temperatures. This average is probably the temperature at which the mist was just ready to form. This temperature is the *dew point* for this time and place.

The *dew point of air is its saturation point*. If the temperature of air is reduced, it will sooner or later reach a point at which it is saturated. If the temperature of the air falls ever so slightly below this point (the dew point) the air must deposit some of its moisture.

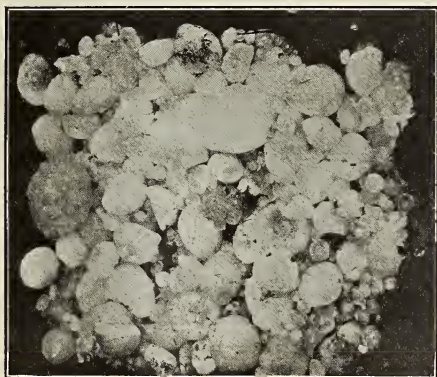
It is important not to think of the dew point as a fixed point of temperature, like that of freezing or boiling. The dew point depends not only upon the temperature of the air but also upon the amount of vapor in the air.

For example, suppose air at a temperature of 80° F. carries about 8 grains of moisture per cubic foot. If the air be cooled to 70° F., it will be saturated. This is the dew point. The slightest drop below this point of temperature will cause the air to give up some of its moisture. But suppose the air at 80° F. had only a little over 4 grains of moisture per cubic foot. The temperature would then have to drop to 50° F. before the air reached its saturation point. Under these conditions 50° F. would be the dew point.

Dew, Fog, Cloud, Rain.—If the cool ground or an object near the ground reduces the temperature of a layer of air

close to it below the saturation point, the air deposits moisture as *dew*. When the temperature of a deep layer of air around us drops slightly below its saturation point, moisture yielded by the air forms in tiny droplets not only on objects at or near the surface of the earth but also on dust particles in the air. The result is a *fog*.

When the temperature of the upper air drops slightly



Courtesy U. S. Weather Bureau

PHOTOGRAPH OF LARGE HAILSTONES

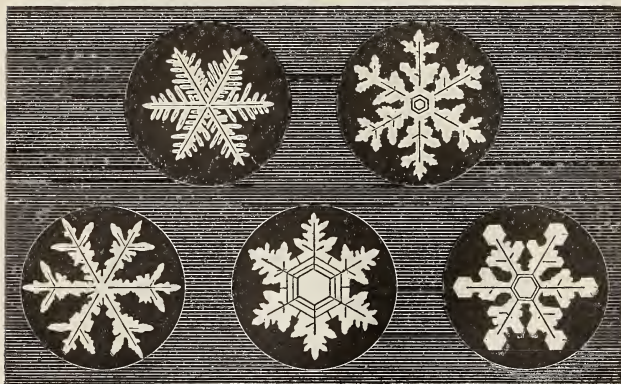
These hailstones fell at Concordia, Kansas, June 23, 1893. The largest hailstone, in the upper middle part of the picture, was $13\frac{1}{2}$ inches in circumference.

below its saturation point, moisture forms in tiny droplets around floating particles of dust, and *clouds* appear. A further drop in temperature will force the air to give up so much of its moisture that the droplets unite into drops too heavy to remain suspended; and so they fall as *rain*.

Frost, Snow, Sleet, Hail.—Dew and rain can form only when the dew point is higher than the freezing point. When the dew point falls below the freezing point, mois-

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ture condenses as *frost* or *snow*. It sometimes happens that moisture condenses as rain high above the earth and then falls through layers of air below the freezing point. The rain drops are frozen and fall as *sleet*. Sometimes these pellets of ice are blown about in the upper air until



MAGNIFIED ICE CRYSTALS

Where water freezes into snow it takes on a great variety of forms. Flat, six-sided crystals of beautifully regular form are the most common.

each pellet collects several drops of rain that freeze together into a larger ice drop. The result is *hail*.

Cooling by Evaporation.—Experiment 60.—(Teacher's Demonstration.)—Mark with a rubber band the height of the water column in an air thermometer (Figure 70). Let fall a few drops of ether or alcohol on the bulb, and notice the change in the height of the column. Place a little ether on the back of the hand. What kind of sensation does it give? (Be careful to use only a few drops of ether, as it is harmful to breathe it too freely.)

When ether was dropped on the air thermometer bulb, it evaporated, and the water column rose just as it did in Experiment 32. We learned in Experiment 38 that

heat is taken up by a liquid as it *boils* away into vapor. This experiment shows that when a liquid *at a lower temperature* changes into vapor, it takes up heat just the same.

Ether is one of a number of liquids, such as gasoline and alcohol, that evaporate more rapidly than water. The more rapidly a liquid evaporates, the more rapidly it takes up heat from its surroundings. That is why ether feels colder to the hand than water. In many places, at the present time, advantage is taken of rapid evaporation in the construction of ice and cold-storage plants.



ICELESS COOLER

The covered vessel is of porous material that looks like white stone. The outside of the vessel is dipped in water twice a week. Evaporation keeps the contents at a low temperature.



FIGURE 70

The canvas desert water-bag (Figure 71) illustrates a simple application of the principle of cooling by evaporation. The water seeps very slowly through the bag, and the evaporation of this seeping water absorbs the heat from the water in the bag and keeps it cool enough to refresh the thirsty traveler.

Evaporation is essential to the health of man and to the thriftiness of plants. The supply of *perspiration* to be evaporated from the skin is automatically regulated by the healthy body for varying temperatures. A similar process in plants is called *transpiration*. Moisture

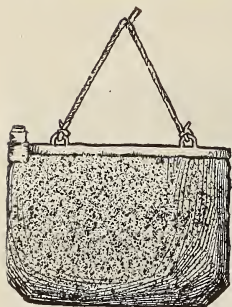


FIGURE 71.—CANVAS DESERT WATER-BAG

is thrown off by the leaves and is evaporated from their surfaces.

Voluntary Project.—To make an iceless refrigerator.—For full instructions, see Farmers Bulletin 927. Describe to the class the method of construction, and explain how it operates. (Figure 72.)

Humidity.—The condition of the air as regards the moisture it holds is called its *humidity*. The amount of vapor present in the air is spoken of as its *absolute* humidity. The amount of vapor in the air as compared with the amount the air would contain if it had all it could hold is known as its *relative* humidity. For example, air at 80° F. is capable of holding almost 11 grains of water vapor per cubic foot. Suppose it actually contains 6 grains of water vapor per cubic foot: It will be loaded then with about $\frac{6}{11}$, or a little more than $\frac{1}{2}$ of the moisture it would contain if it were *saturated* (that is, had all the moisture it could hold). This fraction represents the relative humidity of the atmosphere.

To be considered moist, air must contain about half the amount of moisture it is capable of carrying. If air contains much more than half the moisture it can carry, its humidity is said to be high.

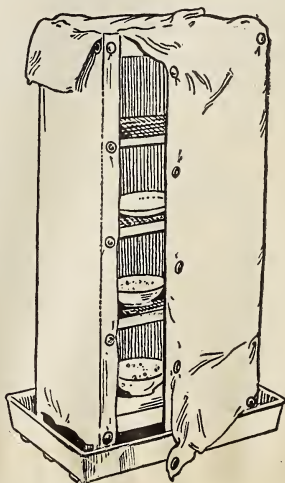
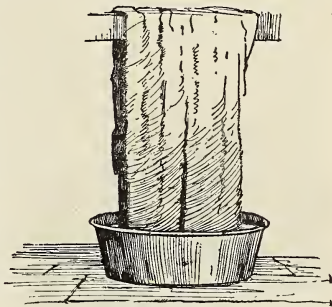


FIGURE 72.—ICELESS REFRIGERATOR

Humidity and Comfort.—The humidity of the air has much to do with our bodily comfort. In quiet warm air, nearly saturated with moisture, the perspiration can not readily evaporate and cool the body. Thus a temperature of 80° F. with a high relative humidity may be more uncomfortable than a temperature of 95° F. with a low relative humidity. On a humid day the perspiration that evaporates brings the air that is near the body closer to the saturation point, and we fan ourselves to move it away and to allow the less moist air to take its place. Any breeze gives relief because it keeps changing the air around the body. An electric fan, although it in no way cools the air, helps evaporate the perspiration by keeping the air in motion. Crowded rooms often become “close” because of a layer of densely humid air around the crowd that results from the moisture of the breath and the evaporation of perspiration. Such rooms may often be rendered quite comfortable by opening more windows or by starting an electric fan, even when there is no way of lowering the temperature of the atmosphere.



A CRUDE DEVICE FOR HUMIDIFYING
INDOOR AIR

The moisture is taken up into the cloth
and is evaporated into the surrounding
atmosphere.

In cold weather or in a room where the temperature of the body is considerably higher than that of the surrounding atmosphere, moist air chills us. This is because moist air is a better conductor of heat than dry air and readily absorbs heat from the body.

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Indoor Humidity in Winter.—The air of most living rooms is too dry. The average outdoor winter temperature in the portion of the country that lies north of the 40th parallel (southern Pennsylvania, middle Ohio, Indiana and Illinois, etc.) is about 25° F. Suppose that air at this temperature is carrying 1 grain of moisture per cubic foot (it cannot carry more than $1\frac{1}{2}$ grains). This air comes into the house and is heated to 70° F. or more. At 70° F., the air could carry 8 grains per cubic foot. If no more moisture is added indoors, the relative humidity is only $\frac{1}{8}$, or $12\frac{1}{2}$ per cent. This is twice as dry as air over a desert.

Such warm dry air is “thirsty” air. If you do not furnish water for it to “drink,” it will take moisture from any source it can reach. It causes perspiration to evaporate very rapidly and thus makes us cold even though the temperature of the room be high. It keeps the skin dried out and sometimes produces “winter itch.” It dries out the membranes of the nose, throat, and lung passages, and makes us more liable to colds, coughs, bronchitis, and pneumonia. It is injurious to the eyes and makes us nervous and irritable. Such air dries moisture out of the glue in furniture joints and leaves it loose and rickety. It warps woodwork, shrinks hardwood floors, and tends to shrivel up everything in the house.

Why do bureau drawers often “stick” in summer, but slide easily in winter? From what has been said we may understand the changes of moisture content in the air of a refrigerator. The air nearest the ice is coldest, therefore, it deposits moisture (with odors) on the ice. As the air circulates (page 137) it gets warmer and takes up moisture. From what is the moisture taken? What should be done with foods in a refrigerator that we wish to keep moist?

Voluntary Project.—To determine whether the air in living rooms contains sufficient moisture.—Select two thermometers that register exactly alike when placed side by side in a room. Fasten them

carefully to a block of wood, two or three inches apart. Cover the bulb of one with one thickness of clean dry linen. Let the linen be of sufficient length to dip down into a dish. Boil water for ten minutes to rid it of lime and set it aside to cool to about the temperature of the room. Fill the dish with this water and allow the end of the linen to hang down in it. This is a homemade *hygrometer*, for measuring moisture in air. (Figure 73.)

The water will soon saturate the linen and moisten the bulb. Now fan the air briskly over the wet bulb, watching the reading of this thermometer from time to time until the mercury ceases to fall. Compare the lowest reading of this wet bulb with the reading of the dry bulb thermometer.

N. B. This project may be carried out with one thermometer if two are not to be had. Take the dry bulb reading first. Then arrange the same thermometer in the way indicated above for a wet bulb reading. Compare the two readings.

To have approximately the right amount of moisture in the room when the temperature is from 65° F. to 75° F., the wet bulb of a hygrometer should read from 9 to 13 degrees lower than the dry bulb. If the difference is less, the air contains too much moisture. With too much moisture, as we have learned, the air is likely to feel muggy if the temperature is high, or chilly if the temperature gets down to 65° F. If the difference is greater than thirteen degrees, the air of the room is too dry. If the difference runs to as much as 20 degrees, your room is drier than a desert.

The reason why these comparative readings show relative humidity is easy to understand. Evaporation of

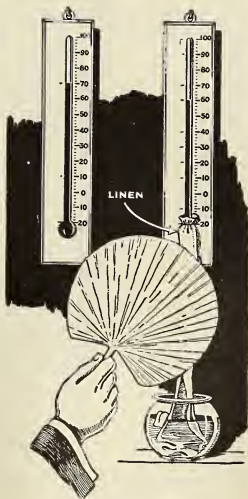


FIGURE 73

moisture from the linen around the wet bulb takes up heat and lowers the temperature of the mercury. If the air were saturated with moisture, there would be no evaporation from around the wet bulb. No heat would be taken up by evaporation and so the reading of the thermometer would remain the same. If the air in the room is dry, it will "drink up" moisture rapidly. The drier the air, the

faster the moisture will evaporate; and the faster the moisture evaporates the more heat it takes up from the wet bulb. If the difference in readings between the wet and dry bulb thermometers is very great, the air in the room must be very dry.

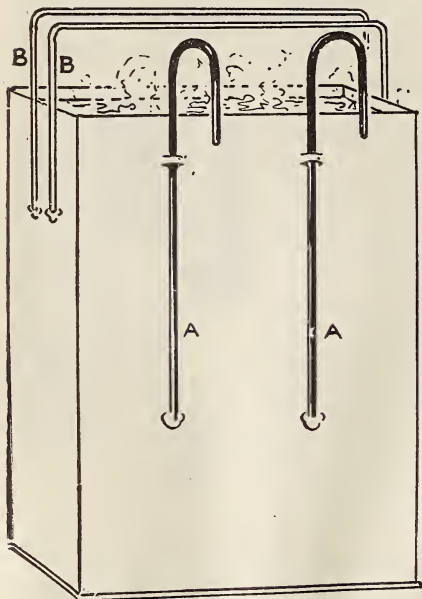


FIGURE 74.—HOME-MADE HUMIDIFIER FOR STEAM OR HOT WATER RADIATOR

This is a galvanized iron tank provided with hooks to attach it to the radiator. The wires, B B, are used to support cheesecloth or any other porous cloth, the ends of which hang down into the water. The water rises in the porous cloth and is evaporated rapidly by the warmth of the radiator.

Adding Necessary Moisture to Indoor Air.—In the interest of the conservation of health, as well as of fuel and of furniture, open vessels of water (humidifiers)

should be kept on stoves, radiators, or registers, in order to keep the air of living rooms moist. Hanging up cloths, the ends of which are in pails of water, will serve the purpose even better, because they increase the surface from which evaporation takes place and thus furnish more water to the air in less time. (Figure 74.) There are many patented devices for humidifying, but the principle on which all of them are constructed is the same as that of the home-made humidifier. A temperature of between 65° F. and 70° F. will make a room comfortable if there is sufficient moisture in the air.

Voluntary Project.—To contrive a device for humidifying indoor air.—Report the plan to the class. Investigate commercial devices for this purpose and report to the class how they are made and how they operate.

III. PRESSURE OF THE ATMOSPHERE

We live at the bottom of a veritable sea of atmosphere. Measurements made in various ways indicate that this sea of air covers the entire face of the earth to a depth of at least 100 miles, probably more.

We found by Experiment 46 that air has weight. Twelve cubic feet of air at sea level weigh about one pound. In other words, the air in a room 36 x 34 x 10 (at sea level) would weigh about half a ton.



COMMERCIAL HYGROMETER

Commercial hygrometers are accompanied by charts that enable one to tell exactly the relative humidity of the air.

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Experiment 61.—Pump air with a bicycle pump into a basket ball. As soon as the walls are rounded out, but not tight, feel the leather casing. Pump in more air and feel the walls again. Do the walls feel “harder” to the touch than they did the first time?

Apparently air was compressed into the basket ball. Pumping air into a bicycle tire also shows how a great deal of air may be compressed into small space. It can readily be seen that if air has weight and can be compressed, the upper air presses down with a tremendous weight on the air near the earth’s surface and makes the bottom of the sea of air much denser and heavier. For that reason, nearly three-fourths of the atmosphere is compressed into the layer below the top of the highest mountain.

The Atmosphere Exerts Pressure Equally in All Directions.—**Experiment 62.**—If a tin can with a tightly fitting screw cap



FIGURE 75

can be easily procured, boil a little water in it, having the screw cap open so that the steam can readily escape. While the water is still strongly boiling, quickly remove the can from the heat and tighten the cap. Be sure not to tighten the cap

before removing the can entirely from the heat. Set the tin thus closed upon the desk and observe. What happens as the steam condenses?

Experiment 63.—By means of an air pump exhaust the air from a pair of Magdeburg hemispheres. (Figure 75.) Now try to pull the hemispheres apart. Can it be done as easily as before the air was exhausted?

Experiment 64.—Fill a glass tumbler even full of water and press upon it a piece of writing paper. (Figure 76.) Be sure that the paper fits smoothly to the rim of the tumbler. Take the tumbler by its base and carefully invert it over a pan. Does the paper fall off? If not, why not? While the tumbler is in the inverted position, insert the point of a pencil between the paper and the rim of the tumbler. What happens?

If the air were a solid its crushing weight would all be directed downward. But since air is a gas and the par-

ticles of a gas move easily over one another, the pressure of air is exerted equally in all directions. We do not feel the pressure of the atmosphere because the pressure of blood and of air inside us balances the pressure of the atmosphere from without.

When the can in Experiment 62 was open, full air pressure was exerted inside as well as outside the can. When the steam and hot air in the closed can cooled they occupied less space and pressed with less force against the inside of the can. The full pressure of the atmosphere on the outside bent the walls of the can inward until the inside pressure equaled the outside pressure. If all the air and water vapor could have been removed, the can would have been crushed flat.



FIGURE 76

With the atmospheric pressure lessened inside the Magdeburg hemispheres, the full atmospheric pressure on the outside held them together. In Experiment 64 the inverted glass kept the atmosphere from pressing down on the surface of the water immediately under it. The upward pressure of the atmosphere on the paper was greater than the weight, or downward pressure, of the water.

If two egg-shells, with their contents removed—one of them with the holes left in it, and the other completely sealed—should be sunk to a considerable depth in water, which one would be crushed by the pressure of the water, and which would not? This illustrates why objects on the surface of the earth are not crushed by the pressure of the air.

When aviators go as high as five or six miles, they may bleed at the mouth and nose. Why? They also have to carry oxygen bags. Why?

Why do papers and dust and other light objects swirl into the trail of a rapidly moving train? Why will two drinking glasses stick together if one is placed inside the other immediately after being taken out of hot water? Why is it necessary to run a knife under the edge

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of the cover of a fruit jar in order to remove it after the contents have cooled?

Why Water Rises in a Lift Pump.—Experiment 65.—Fill a bottle with clean water and fit it tightly with a rubber stopper having two holes in it. Plug one of the holes tightly with a glass tube one end of which has been closed by heating in a Bunsen burner. Through the other hole put an open glass tube 10 to 15 cm. long. See that both tubes fit tightly in the stopper and that the stopper fits tightly in the bottle. (Figure 77.) Now attempt to “suck” the water out of the bottle through the open tube. Does it come out freely? Pull out the glass plug. Does it come out any better? If so, why?

When you sucked on the tube, you withdrew air from it. This tended to create a vacuum—a place where there is no air and consequently no air pressure. As soon as



FIGURE 77

the air pressure was removed from the surface of the water *inside the tube*, the pressure on the rest of the water in the bottle forced a column of water up the tube.

This illustrates the principle of the ordinary “lift pump,” which as you see is not a lift pump but an air pressure pump. (Figure 78.) When the piston of the pump is raised from the bottom of the cylinder a partial vacuum is created in the cylinder. The air pressure on the water in the cistern forces the water up the pipe and through the valve B into the cylinder. When the piston descends, the valve B in the bottom of the cylinder is closed by the weight of the water and the valve A in the piston opens, allowing the water to flow through to the upper side of the piston. As the piston is once more raised, the valve A closes and the water above the piston is lifted and flows out the

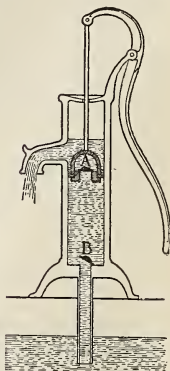


FIGURE 78.—DIAGRAM OF A LIFT PUMP

spout. At the same time air pressure is again forcing more water up the pipe and through the valve B into the cylinder. The water continues to rise into the cylinder and to be lifted out as long as the pump is worked.

In a perfect vacuum, the pressure of the atmosphere would support a column of water about 33 feet high. But since it is impossible to create a perfect vacuum with the piston and valves, water never rises as high as this in a lift pump. In practice the average limit is about 27 feet.

Why is it better to have two holes in a can from which liquid is to be poured? What makes water gurgle from a small-necked bottle? What makes soda water rise in a straw? Why can you suck at the mouth of a small bottle and make it "stick" to your tongue? Why does ink rise into the barrel of a self-filling fountain pen?

Measuring Atmospheric Pressure.—Lift pumps were used for two thousand years before anyone successfully explained their operation.

In 1640, a wealthy Italian duke had a deep well dug for himself near Florence. But after the well was dug, he discovered that the best pump obtainable would not lift the water more than about 25 feet. He appealed to Galileo, the great scientist, to help him. Galileo knew that under the most favorable circumstances a column of water would not stand higher than about 33 feet in a tube, but he could not explain the fact. He was too old and feeble to seek out the reason, and so he passed the problem on to his friend and pupil, Torricelli.

Torricelli set about first to find out why the column of water rose at all in the tube. He reasoned that if the weight, or pressure, of the air supported the column of water, it ought to support a column of any liquid. Of course the heavier the liquid the shorter the column that could be supported. He concluded to try the experiment with mercury, which is 13.6 times as heavy as water.

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Since the column of water stood about 33 feet high, he reasoned that the mercury ought to stand 33 feet $\div$ 13.6 or about 30 inches high. To test his conclusion, he performed the following experiment, which is known to this day as Torricelli's Experiment.

Experiment 66.—(Teacher's Demonstration.)—Take a thick-walled glass tube of about $\frac{1}{2}$ cm. bore and 80 cm. length. Close it at one end. Fill the tube with mercury. (Be sure to place the closed end of the tube in a large vessel so as not to waste the mercury if you spill it.) Place the thumb tightly over the open end of the tube and invert it in a vessel of mercury. If you are at or near sea level, the mercury column will drop to a height of about 75 cm. (about 30 inches) and will stand there. (Figure 79.)

The space above the mercury is without air, and therefore no atmospheric pressure is exerted at the top of the column of mercury. The column of mercury is pressing down on the surface of the mercury in the vessel. The atmosphere is also pressing down on the surface of the mercury in the vessel. The one pressure balances the other.

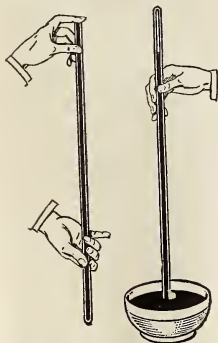


FIGURE 79

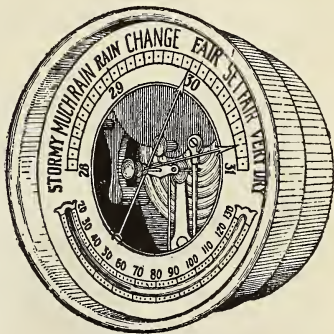
It makes no difference what the diameter of the column of mercury is; it will stand at just the same height. If we want to know the weight of a column of air measuring an inch square at the base and extending from the bottom of our sea of atmosphere to its upper limit, we have but to weigh a column of mercury an inch square at its base and about thirty inches tall. Such a column weighs about fifteen pounds. Therefore, the pressure of the atmosphere is about fifteen pounds to the square inch at sea level.

The Barometer.—If the tube used in Torricelli's Experiment is fixed in an upright position, and the height of the mercury marked from time to time, it will be found that the height of the mercury column changes slightly, thus indicating greater or less atmospheric pressure. In Torricelli's Experiment, therefore, we had a mercurial *barometer* in rough form.

On account of the movements of the air due to heating and cooling and to other causes, the pressure of the atmosphere at any place on the earth's surface is liable to change.

Since measurement of atmospheric pressure is of great importance in the study of atmospheric conditions, it is necessary to have an instrument by which changes in pressure can be readily measured. In the best form of this instrument means are provided for determining the height of the mercury column very accurately.

The mercurial barometer is the most reliable instrument for measuring atmospheric pressure, and so it is used in all weather stations. But because it is awkward to carry, traveling scientific parties use instead what is known as the *aneroid* barometer. This consists in general of an air-tight metal box, from which most of the air has been exhausted. It has a thin corrugated top that readily bends a little inward or outward with changes in atmospheric pressure. The slightest bending of the metal top is conveyed by a series of levers to a pointer.



ANEROID BAROMETER

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This pointer moves over a dial and indicates the readings on a scale.

Instruments called *barographs* are constructed in which a long lever provided with a pen point is attached to the aneroid and made to record on a cylinder revolved by clockwork. Thus a continual record is made of barometric readings.

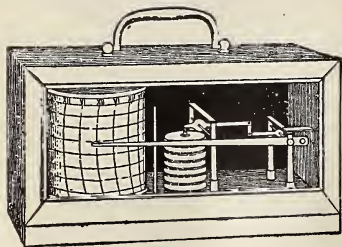
Determination of Height by a Barometer.—Experiment 67.

—Carry an aneroid barometer from the bottom of a high building to the top. Note the reading of the barometer at the bottom and again at the top. Why is the barometer lower at the top of the building?

A Frenchman, Pascal, repeated Torricelli's experiment with other liquids, and was satisfied that Torricelli was

right in his conclusion.

He further reasoned that the deepest column of air would support the highest column of mercury. The mercury should, therefore, stand highest at sea level, and gradually fall as the barometer is carried above sea level. Since he could not test his theory near Paris, he wrote his



BAROGRAPH

This is arranged so as to record the air pressure automatically for a week at a time.

brother-in-law to make the test by taking a Torricellian tube up a mountain near the latter's home. Pascal was gratified to learn that at a height of 3000 feet, the mercury stood about three inches lower in the tube than at sea level.

It may roughly be estimated that the fall of $\frac{1}{16}$ of an inch in the height of the mercury column indicates a rise of about 57 feet, or that the fall of a millimeter indicates a rise of about 11 meters. These values are fairly reliable

for elevations less than a thousand feet, under ordinary temperatures and pressures.

At the height of 25 miles the barometric column would probably not be more than $\frac{1}{25}$ of an inch high.

Why Balloons and Airships Ascend.—We have seen that the atmosphere is densest at its lowest level and becomes less and less dense as we ascend. Balloons and



International Photo

THE SHENANDOAH, THE FIRST GIANT DIRIGIBLE CONSTRUCTED IN AMERICA

In 1925, this beautiful airship was destroyed by an unusually severe storm. Her average speed was 60 miles an hour; cruising radius, 4000 miles.

airships are filled with a gas that is lighter than the lower atmosphere. An airship rises, therefore, to a point where the weight of the gas container and its burden is the same as an equal volume of air. At this height it floats on the denser air beneath, much as a ship floats on water.

Hydrogen has always been the most commonly used gas for balloons and airships, because it is the lightest gas known. But if this gas leaks from its container and comes in contact with a spark, a terrific explosion and tragic results may ensue. For this reason, the United States Navy had the Shenandoah and the Los Angeles, the largest airships in the world, filled with helium, a non-inflammable gas (page 72). Helium is almost as light as hydrogen and is in every other way superior to it for this use. The only reason it has not been more generally used is that helium is a much rarer gas and is a great deal more expensive to prepare.

Helium for United States Airships.—Enough helium gas is now available in the United States to keep filled and ready for service two hundred airships of the size of the navy dirigible, Shenandoah. The chief sources of the gas are the natural gas wells of Texas. The great problem is to separate it from the fuel gases and still retain the fuel gases for industrial purposes. This problem has been solved.

Another problem in the use of helium is the conservation of the gas during the manipulation of the airship. A modern dirigible, by means of its engines and steering apparatus, may travel with or against the wind and may ascend or descend, but it must maintain a pretty steady weight. If its load be too much lightened, it can descend only with difficulty.

When a dirigible starts from its hangar for a long trip, with its load of gasoline, it is much heavier than after it has traveled far enough to lower its gasoline supply. In order to get back to the ground under such circumstances, some of the helium gas had to be let out in order to increase the relative heaviness of the airship. Something had to be done to avoid this waste.

In the fall of 1923, the Shenandoah made a trip to Saint Louis. When it reached there, it had a low supply of gasoline, but the crew wanted to land without loss of helium. The dirigible was therefore driven, by a quick dive, down near the ground, and was hauled to earth by three hundred men tugging at its ropes.

Clearly this method of landing is not always practical. But a way has now been found of condensing into water the vapor produced during the combustion of the gasoline (page 90). This water is caught and stored in tanks. This is known as the "water-recovery" system. As the gasoline supply is lowered by burning, the supply of water condensed from the vapor of combustion is correspondingly increased. Thus the dirigible maintains a fairly steady weight and may ascend or descend at the pleasure of the crew.

IV. MACHINES THAT MAKE USE OF AIR PRESSURE

The Siphon.—Experiment 68.—Fill an eight-ounce bottle with clean water and fit it tightly with a two-holed rubber stopper. Through one of the holes in the stopper insert a tightly fitting glass tube, which reaches nearly to the bottom of the bottle and extends an inch or two above the stopper. Attach to this glass tube a clean rubber which is long enough to reach below the bottom of the bottle. Fit a sealed glass tube so that it can be readily inserted in the open hole of the stopper. (Figure 80.)

"Suck" water out of the end of the rubber tube hanging below the bottom of the bottle. As soon as the water begins to flow, withdraw the mouth without raising the tube. The water will still continue to flow. Insert the sealed glass tube in the open hole of the stopper. The water stops flowing. Pull out the glass plug. The water begins to flow again. Any bent tube arranged in this way, with one arm longer than the other, is called a *siphon*.

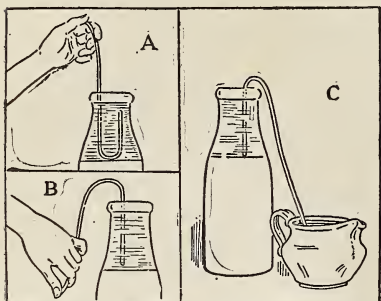


FIGURE 80

The pressure of the atmosphere on the water at the mouth of the short tube is practically the same as it is at

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the end of the long tube. If these were the only two forces, they would balance and there would be no flow of water. But the weight of water in the long arm is of course greater than that of the shorter column. (Figure 80.) This turns



DIAGRAMS SHOWING HOW TO SIPHON CREAM FROM
A MILK BOTTLE

the scale in favor of the long arm and the water falls out of it.

As the water flows out of the long arm, it tends to leave it empty; that is without air and therefore without air pressure. Therefore the weight of air pressing on the surface of the water

in the bottle immediately forces water up the short arm to take the place of the water flowing out of the long arm. The water continues to flow as long as the water-column *ab* is longer than the water-column *cd*, or until the level of the liquid falls below the mouth of the short arm.

Of course the length of the short arm must not be greater than 33 feet. Why? Why did the insertion of the sealed glass tube stop the flow of water?

Vacuum Cleaners.—Experiment 69.—If an electric fan is available throw a small amount of flour at the back of the rapidly revolving fan. What happens?

The fan whips air off the ends of its blades. This tends to create a vacuum behind the fan. Atmospheric pressure forces air into this space that is being emptied, carrying dust and flour particles along.

This illustrates what happens in the ordinary vacuum cleaner. The fan in the vacuum cleaner forces air into the cloth bag. This creates a partial vacuum at the mouth of the machine. Atmospheric pressure forces dust and dirt-laden air through the blades and into the closely woven bag, which sifts out and collects most of the dust.

Advantages of the Vacuum Cleaner.—The vacuum cleaner is not only a labor-saving device. It helps to keep the indoor air clean, and this has an important bearing on our health.

Experiment 70.—Allow a beam of light to enter a darkened room through a small hole in a curtain. Note as carefully as you can the different things in the air that the beam of light reveals.

In the preceding experiment we observed that the air contained something more than the gases and moisture which we have learned are in it. There are many solid particles floating in the air. There were little shreds of cloth and paper, pieces of dust and soot, and many other things. The beam of light, however, did not reveal everything that was floating in the air. There were many living organisms, tiny plants (*bacteria*) too small to be seen except by the aid of a high-power microscope.

These minute living things are scattered all through the air, sometimes living on dust particles and sometimes unattached to anything. Only a few of the bacteria are harmful, and they are usually not very abundant. Sunlight kills most of them in a short time, but moisture and darkness furnish conditions favorable for them. They are particularly abundant in the dust of the street and wherever foul refuse accumulates. When they get into a house they settle and multiply rapidly if they happen to light upon a warm, moist place where the sunshine is not too bright. Ordinary dusting and sweeping simply

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scatter them about and keep them floating in the air for hours, for us to breathe. Carpet sweepers and oiled dust cloths do much to prevent stirring up the dust and bacteria, but vacuum cleaners are even more effective.

Compressed Air.—As was shown in Experiments 8 and 61, the volume of air can be very much decreased by pressure; that is, much air can be compressed into small space. Air is elastic. When any of it has been compressed into small space, it exerts pressure to return to its original volume.

The more we decrease the volume, the more the pressure of the confined air increases. If air is compressed to one-third its original space, it will exert three times as much pressure as it did before. When the pressure is removed it regains its original volume. A puncture in an inflated automobile tire shows how rapidly and forcibly air will expand from its greater density under pressure to the density of the surrounding atmosphere.

These properties of compressibility and expansion which air has, in common with other gases, have many practical applications. One of the most familiar applications is in the air pumps of garages. Compressed air is also used to apply brakes on street cars, steam engines, and railway coaches. It is used to blow whistles, to ventilate mines and large buildings, and to operate heavy hammers, rock drills, and riveting machines.

Force Pump.—The force pump illustrates a use of compressed air. An "air cushion" is used to deliver a steady stream of water to a point higher than the mouth of the pump. In the force pump, the water rises into the cylinder when the piston is raised, exactly as in the ordinary lifting pump. The piston has no valve, and so when it descends it forces the water out through the pipe

E (Figure 81) into the air chamber *D*, thus compressing the air in it. The valve *C* keeps the water from running back when the piston is lifted. While the piston is ascending, the pressure of the air cushion *D* forces a steady stream through the pipe *A* to the tank above.

The force pump is sometimes used to fill tanks in attics of farmhouses so as to provide private water-systems. The principle of the force pump is used in the more complicated pumps for water-works, fire engines, and mines.

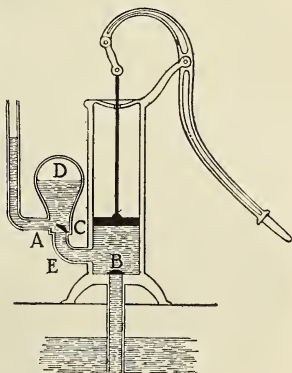


FIGURE 81.—DIAGRAM OF A FORCE PUMP

Heat Produced by Compression and Cooling Produced by Expansion.

—Experiment 71.—(Teacher's Demonstration.)—Have a five-pint glass bottle fitted with a two-hole rubber stopper. Pass through the holes in the stopper a chemical or air thermometer and a short glass tube. The lower end of the glass tube which extends into the bottle should be kept as far as possible away from the bulb of the thermometer, so that when the air is exhausted or allowed to enter the bottle there will be no movement of the air near the bulb of the thermometer. The upper end of the mercury column of the thermometer must be visible above the stopper. (Figure 82.)



FIGURE 82

Attach the glass tube to an air pump by means of a thick-walled rubber tube. Note the temperature of the thermometer within the bottle and also of the air outside. Quickly exhaust the air from the bottle, carefully noting the action of the thermometer. See that the temperature of the air in the room does not change during the experiment. Allow the air quickly to enter the bottle and note the action of the thermometer. The temperature inside the bottle changes as the air is quickly exhausted, or as it is al-

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lowed to enter the bottle again and thus to increase the density of the air in the bottle.

It has been found that when air or any other gas expands, it absorbs heat and cools its surroundings; and when it is compressed, it yields heat and warms its surroundings. This heating and cooling by changes in the density of gas is called *adiabatic* heating or cooling. It is taken advantage of in the manufacture of liquid air and is the same principle which is utilized in cold-storage plants. This property of air has much to do with developing our wind circulation and storms.

The heating effect of compressing air can be well seen when an automobile tire is filled. No matter how well the piston of the pump may be oiled, as the density of the air in the tire begins to increase, the pump will grow warm rapidly. This rapid heating cannot be due to friction, as the pump is not being worked any more swiftly than at first. It is due to the greater compression of the air. As this compression increases, the heating increases, the effect of friction in a well-oiled pump being of small effect.

Liquid Air.—About twenty years ago, compressing machinery was improved to such a point that it became possible to compress the gases of the air into a liquid. So much heat is released from the air by the enormous pressure that the temperature of the liquid air is about 200° below zero.

Compared with this liquid air, the air we breathe is as hot as a furnace. If liquid air falls on the floor, it hisses and evaporates as water does when it falls on a red-hot stove.

Liquid air left in an open vessel returns to its gaseous form in a few minutes. Confined in an ordinary sealed vessel, it absorbs heat from its surroundings, returns to gaseous form and explodes from its container.

Sir James Dewar, an English scientist, realized that if a vessel could be contrived that would prevent liquid air from rapidly absorbing the heat of its surroundings, the air could be kept longer in a liquid state. His efforts to invent such a vessel were crowned with success. Strangely enough, this *Dewar flask* found a much wider commercial use as the well-known *thermos bottle* (page 137.)

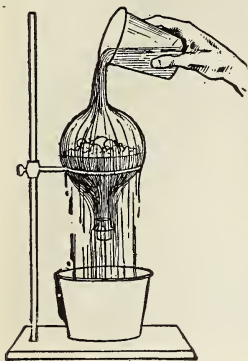


FIGURE 83

Pressure and the Boiling Point. — Experiment 72. — (Teacher's Demonstration.) — Fill a strong 500 ccm. round-bottomed flask about one-third full of water. Boil the water. While the water is briskly boiling, remove the flask from the heat, quickly close its mouth with a rubber stopper, and invert it in a ringstand. (Figure 83.) (Be sure not to insert the stopper until

the flask is fully removed from the heat.) Pour cold water upon the flask. The water will again begin to boil.

In this experiment the steam was condensed by the sudden lowering of the temperature. The condensation of the steam relieved the pressure on the surface of the water and the water in the flask began to boil again although it had become considerably cooler than when it was first boiled. Thus it appears that if the pressure on the surface of water is decreased, the water will boil at a lower temperature. Advantage is taken of this in condensing milks and sirups. The liquids are heated under hoods from which air is continuously exhausted. The water is thus "boiled away" at so low a temperature that there is no danger of scorching the sirup or the milk.

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Pressure Cooker.—On high mountains where the air pressure is considerably less than at sea level, water boils at less than 100°C .

In Denver it boils at 95°C .; in the City of Mexico, at 92°C .; in Quito, Ecuador, at 90°C . Because water boils in such places at a lower temperature, it takes longer to boil food until it is "done." To hasten the process of cooking by boiling in high altitudes, pressure cookers are often used. The high pressure developed by keeping the steam imprisoned raises the



PRESSURE COOKER

boiling point of the water within. The contents of the cooker may thus be brought to a temperature of 170°C . or even more. This intense heat reduces the time of cooking and thus saves fuel.

SUMMARY

The gaseous envelope of the earth is called its atmosphere. The chief gases of the earth are oxygen, which is necessary for animal life; nitrogen, which dilutes the oxygen; and carbon dioxide, which is indispensable to plant life.

The atmosphere at all times and under all conditions contains some moisture. Water exposed to air evaporates. Warm air can hold more moisture than cold air. When warm air saturated with moisture is cooled it must deposit some of its moisture. The saturation point of air at any

temperature is called the dew point. Moisture may be deposited from the air as dew, fog, cloud, or rain, frost, snow, sleet, or hail. The form the moisture takes depends on the surrounding temperature and the height above the earth at which the moisture condenses. When a liquid evaporates it takes up heat from its surroundings.

The amount of moisture in the air, or its humidity, has much to do under varying conditions of temperature with bodily comfort and health. In cold weather air in the majority of heating buildings is too dry. There are many means of adding moisture to indoor air; and in cold climates, every home should have devices for keeping the air moist.

Air like every other substance has weight. Since the atmosphere is probably at least 100 miles deep and air can be compressed, it follows that the air next to the surface of the earth is much denser and heavier than the upper air. Since the atmosphere is a gas, the pressure of air is exerted not simply downward but equally in all directions.

When air pressure is removed from above any part of the surface of a liquid, atmospheric pressure on the rest of the surface will force the liquid toward where the pressure has been removed. This principle is responsible for the device known as the lift pump. The reason why water rises in a lift pump was discovered by Torricelli. He calculated that the atmosphere exerts a pressure at the surface of the earth of 15 pounds to the square inch. His experiment with the mercury tube led to the invention of the barometer, an instrument for measuring air pressure. This has been put to use in forecasting weather conditions and in determining altitude. The reason why balloons and airships ascend is that they are lighter than the lower layers of atmosphere and so they rise and float on the heavier air beneath.

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The siphon and the vacuum cleaner make use of atmospheric pressure. Compressed air is used in many practical ways as in the force pump, brakes on street-cars, in the ventilation of large buildings and mines, and in the operation of heavy hammers, rock drills, and riveting machines.

QUESTIONS

What gases are in the atmosphere and what are their main uses?

What is evaporation? How does it differ from boiling?

What is meant by dew point?

What are the causes of dew, fog, cloud, rain? Of frost, snow, sleet, hail?

What effect has evaporation of a liquid on temperature? Why?

What is humidity? What is the relation of humidity to comfort? Of indoor humidity in winter to health?

How can we determine whether indoor air has sufficient moisture for comfort and health?

Describe a device for humidifying indoor air.

Why does air exert pressure at the surface of the earth? Why does the atmosphere exert pressure in all directions?

Why does water rise in a lift pump?

How did Torricelli contrive to measure atmospheric pressure?

What is a barometer? Why may it be used to determine altitude?

Why do balloons and airships ascend?

How do dirigibles manage to maintain fairly steady weight instead of becoming lighter as their gasoline supplies are lowered?

Explain the operation of a siphon.

How does a vacuum cleaner "suck up" the dirt?

What are some of the mechanical uses of compressed air?

Explain the operation of a force pump.

What are the temperature effects of compressing and of expanding air?

What is liquid air?

What effect on the boiling point of liquids has the lowering of atmospheric pressure? The increasing of atmospheric pressure?

Explain how a pressure cooker hastens the process of cooking.

CHAPTER IX

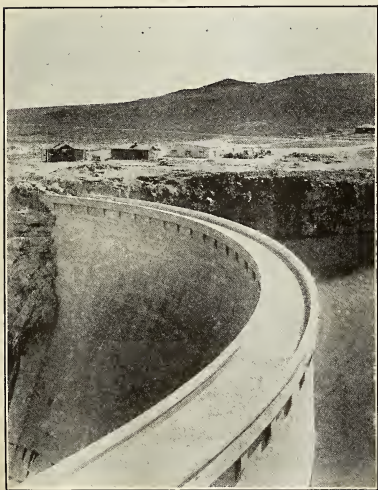
THE WATERS OF THE EARTH

*Water its living strength first shows
When obstacles its course oppose.*—Goethe.

Water Is Essential to Our Existence.—Water is found to some extent everywhere on the earth's surface. It is in the air about us, and in the rocks and soil beneath us. It

has sculptured the earth's surface and helped to grind out the very soil it moistens. It has carried rock-grist of its own grinding to the sea and has rebuilt it into other rocks.

It makes up a very large part of the weight of all living things and is necessary to their existence. Man's homes and settlements have always been determined first by the available supply of wa-



SALMON RIVER DAM, IDAHO

A typical irrigation dam in the United States.

ter for himself, his flocks, and his crops. Water routes of travel were of next importance.

Modern conditions have added to man's original needs many other uses of water in the home, in industries, and in land and water transportation. Modern railway transportation and the growth of cities have only emphasized the necessity of extending our waterways. The increasing cost and reckless waste of fuel have turned our attention to the streams and waterfalls as sources of power. In fact, our increasing need of water for all purposes has compelled us to take measures for the preservation of our lakes and streams and to build reservoirs for the saving of flood waters.

Water is a destroyer and a builder. The earth has been likened by some writers to a water engine, since water has played such an important part in its history. But this comparison is misleading. We have seen that water without air would be of no service to man. Both are essential, and both need the controlling energy of heat to make them useful. Water and air are the two indispensable tools with which heat does its work.

I. COMPOSITION AND FORMS OF WATER

Composition of Water.—Pure water is a colorless, odorless, tasteless liquid. In Experiment 11, we learned that water is composed of two colorless, odorless, tasteless gases, hydrogen and oxygen. They are united in the molecule of water in the proportion of two atoms of hydrogen to one of oxygen—indicated by chemists with the symbol H_2O .

Hydrogen and oxygen are of enormous importance to us in more ways than this alone. They enter into the make-up of all living things, not only in the form of water, but in the forms of innumerable compounds of living tissue. Both elements are present in all natural fuels—

because these fuels are all derived from things that once lived.

Review the findings of Experiments 11 and 26B. Less than one hundred and fifty years ago, water was believed to be an element. In 1784, Sir Henry Cavendish, an English scientist, discovered that the burning of a jet of hydrogen in oxygen produced water as the resulting compound. Hydrogen is the lightest of all known substances, much lighter than air. Oxygen is sixteen times as heavy, slightly heavier than air. In other words, an atom of oxygen is sixteen times as heavy as an atom of hydrogen, eight times as heavy as two atoms of hydrogen; and so while hydrogen makes up two-thirds of the *volume* of water, oxygen makes up eight-ninths of its *weight*.

Water as a Carrier of Heat.—Review.—Experiments 37, 38, 39, 59, and 60 deal with the three forms of water and with the effect of heat on them. Review the findings of these experiments.

We have already learned that it takes more heat to raise a given mass of water one degree of temperature than to cause a like increase in temperature in an equal mass of almost any other substance. This was shown in Experiment 37. When water cools, it gives out the heat it took up when its temperature was raised. It is for this reason that hot water furnaces are so efficient, and that farmers sometimes in winter carry down tubs of water to keep their cellars above the freezing point. For the same reason orange groves are often irrigated when a heavy frost threatens.

The Force of Freezing Water.—Experiment 73.—Allow a test tube filled with water and tightly corked, to freeze. What happens? If the temperature of the air is not cold enough, place the test tube in a mixture of chopped ice and salt, or better, chopped ice and ammonium chloride (sal ammoniac), and allow it to remain for some time.

At the moment water solidifies into ice, it expands with such tremendous force that it exerts a pressure of more than 100 tons to the square foot. No wonder it bursts water pipes, splits rocks and concrete sidewalks, and heaves the foundations of buildings that have not been laid below "frost line." After ice has once formed, it again begins to contract as the temperature is lowered, but it never reaches the density of water.

II. WATER AS A SCULPTOR

What Becomes of the Rain.—When rain falls upon the ground, it may do one of three things. It may run rapidly off the surface and quickly join the streams and rivers which bear it to its final goal, the sea; it may evaporate from the surface and return to the air; or it may sink deep into the ground.

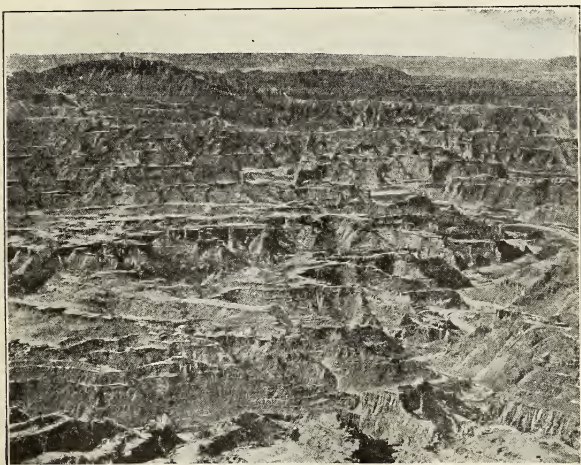
The Work of Running Water.—The run-off most profoundly affects the earth's surface. Gullies and valleys are cut and depressions are filled; in fact, running water is the chief tool which has carved the features of the earth.

From the time when it was first possible for water to exist as a liquid on the cooling crust of the earth, it has been busy tearing down the highlands and building up the lowlands. The water of earth's first rains gathered in streams and began to dig channels, to sculpture the wrinkles of the earth into mountain peaks, and to fill the valleys. Through the ages it has worked restlessly, wearing down crags to low-lying rounded summits, and washing the hills down to the dead level. This sculpturing effect of water in motion is called *water erosion*.

In the eighteenth century, certain men held the belief that the earth was formed altogether by the agency of fire. Other men believed that water was the chief agency in molding it. Now we know that both contenders were partly right. What the work, or the loss, of earth's in-

ternal heat has done to lift portions of the earth's crust above sea level, water has labored steadily through the ages to undo.

Geologists have evidence that in some places mountain chains have been elevated and worn down four times in the history of the changing earth. How many times before that the surface had been uplifted and worn back to the



THE BAD LANDS OF DAKOTA

Running water has so dissected this land as to render it valueless.

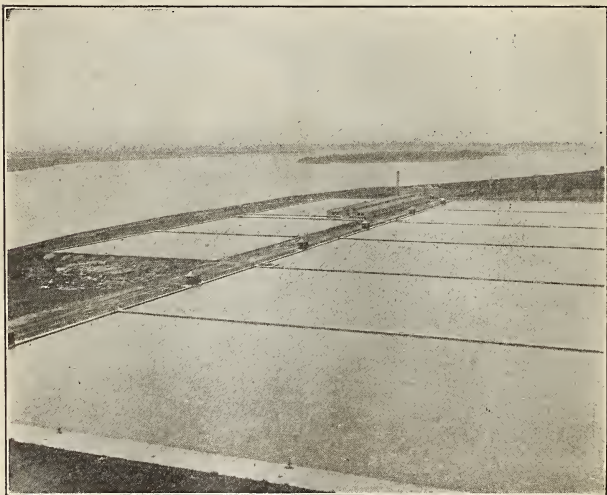
level can not be determined; and how many times hereafter it may occur can not be reckoned. The very region where you live may, at one time, have been far under the sea. It may have been lifted after that into lofty tableland or into snow-covered mountains, which water and other agencies have worn down to their very roots.

The Carrying Power of Water.—Experiment 74.—Into a two-quart glass jar $\frac{3}{4}$ full of water, put two tablespoonfuls of coarse gravel

(not larger than peas), two tablespoonfuls of finer gravel, two tablespoonfuls of sand, and four tablespoonfuls of the finest clay dust obtainable.

Stir the mixture vigorously, until all the solids, including the coarse gravel, have been lifted from the bottom of the jar and churned into the mixture.

Set the jar aside and allow the water to clear. After the water has cleared, observe the layers of material at the bottom of the jar. Which settled first, the heavier or the lighter materials?



QUIET WATER DEPOSITS ITS BURDEN

These are the settling basins of the St. Louis water plant. Muddy river water is pumped into these basins and is allowed to stand until it loses its heavier sediment. The combined capacity of these basins is 245,000,000 gallons.

It was found in Experiment 74 that moving water is able to hold soils in *suspension*. The more violent the motion of the water, the more and the larger particles it holds in suspension. As the water quiets down, it begins to deposit the load it has been carrying. The heaviest materials

are naturally the first to be deposited. Very light particles may remain suspended as long as there is any motion at all in the water, and are slow to settle even after all apparent motion has ceased.

Everyone has observed at some time or other the marked effects of moving water on unprotected soil surfaces. The larger the moving stream, the greater its work. Professor



RESULTS OF A SUDDEN FLOOD

This illustrates the carrying power of water in violent motion. Not only soil but houses and trees as well have been swept away.

Salisbury of the University of Chicago has estimated that the *daily burden* which the Mississippi River carries from uplands to the Gulf of Mexico is so great that it would load 900 trains of 50 cars each, each car carrying 25 tons.

Rivers as Destroyers.—What the rivers are now doing, they have done for ages. Rocks large and small, split from the mountain crags by frost and by the action of the air, are washed down the slopes. The steeper the slope and the more abundant the water, the faster is the process

of erosion. The very burden that the river carries in flood time helps to gouge out its course.

The rushing water dashes the rocks together and breaks them. The chips are carried along, grinding against each other as in a mill. The ceaseless motion of the water, rattling and thumping the bits of stones together, wears off their sharp edges, grinds them smooth, polishes them



LAKE BRIENZ FROM ABOVE INTERLAKEN, SWITZERLAND

A rapidly eroding stream at the right has built a great delta dividing the ancient lake into two parts.

and reduces them into minute particles. These particles make up the larger part of the soil.

As the slope of the river bed becomes more gradual, the water drops more and more of its heavier load and carries along only the lighter particles. Thus the upland streams patiently wear down their courses and join to form even-

usually the slower main stream. The course of the main stream becomes more and more gradual until, still carrying the finer materials gathered along its route, it comes to the long smooth stretches. Here it is no longer cutting down its trough, but has only sufficient slope to enable it to bear along its load of waste. It here deposits upon its valley floor about as much as it takes away.

Rivers as Builders.—When a river enters a body of quiet water, its current is gradually checked and it deposits its material in somewhat the same way as when it emerges upon a flat country. The heavier material is dropped first. The finer material remains suspended longer and is carried far out from the river's mouth. Land formations thus built up are called deltas, from the Greek capital letter Delta (Δ), which has the shape of a triangle. Few deltas have this ideal shape, but in most cases there is some similarity to it.

The delta of the Mississippi is 200 miles long and has an area of more than 12,000 square miles. The river is building its delta out into the Gulf at the rate of $\frac{1}{6}$ of a mile a year. All of Louisiana, and a large part of Alabama, Arkansas, Florida, Mississippi, and Texas were once a part of the Gulf of Mexico. The materials brought down from the north by river waters have literally transformed the sea into dry land. Not far from the mouth of the Po River in Italy is the little town of Adria. In the days of the Romans it was such a famous port that it gave its name to the Adriatic Sea. To-day it is fourteen miles from the coast, and the land which lies between it and the sea has been laid in by the waters of the Po.

Waves as Destroyers.—The work done by the waves in wearing away the land and distributing the waste is next in importance to that of running water. The larger the body of water, the larger are the waves which the wind

raises and the greater their power. Of course the waves accomplish most at high tide and during great storms.

In 1399 Henry of Lancaster, afterward Henry IV of England, returned from his exile and landed at Ravenspur, an important town in Yorkshire, to begin his fight for the crown. A person disembarking at the same place to-day would be so far from shore that he would need to be a



THE ISLAND OF HELGOLAND, NORTH SEA

sturdy swimmer to reach the beach. The entire area of the ancient town has been cut away by the waves and now lies under the sea.

The island of Helgoland in the North Sea is famous as the site of an impregnable German fortress during the Great War. This island is known to have had an area of 120 square miles A.D. 800. Eleven hundred years of ceaseless wave action have whittled its area to $\frac{1}{3}$ of a square mile. Eventually it will probably disappear entirely.

Waves as Builders.—Wherever the waves strike on an unprotected shore, they wear it away.

Unless the material pillaged from the land by the waves falls into too deep water, it is buffeted about by them and broken and worn into small pieces. These are then borne along by the shore currents until they find lodgment in some protected place where they can accumulate. Currents moving loose material with them sometimes form it into bars which tie islands to the mainland or extend into the sea free ends, forming what are called *spits*. A famous example of a land-tied island is that of the great English fortress at Gibraltar. Although now a promontory, it was once an island detached from the coast of Spain.

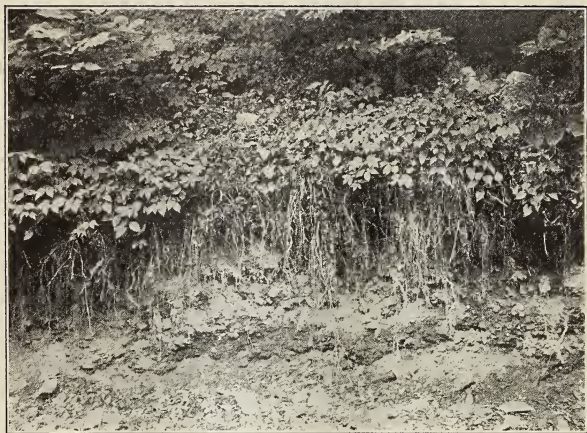
The greatest Mediterranean port of France during the thirteenth century, Aigues-Mortes, has been closed in by wave-built sand bars so that there is no longer access to the sea and only the relics of the former great city now exist. Thus have the moving sea-sands overthrown the plans of men.

III. CHECKING THE FLOODS; FORESTRY; RECLAMATION

Protecting the Upland Soils from Erosion.—When rain drops upon the foliage of trees, its force is broken and it falls to the ground in fine spray. If the ground beneath is carpeted with leaves and decaying vegetation the soil is further protected from erosion. The water readily soaks into the soil made spongy by leaves and roots. When the rain is over, evaporation does not take place rapidly because of the double protection afforded by the shade of the trees and by the leafy carpet. If a region is well supplied with forests so that the rain as it falls is held by the moss, leaves, and roots and protected from evaporation by the foliage, soil water will continue to be supplied to the surrounding open land long after it would have become dry had the forests been removed. Mountain soils have

been found which hold back five times their own weight of water.

Damage Caused by Removal of Forests.—If the trees are cut away the rain splashes down on the unprotected soil. Most of the water runs off the surface, often carrying fertile soil with it. Even the water which soaks into the ground is usually quickly evaporated from the unshaded surface.



HOW ROOTS HOLD THE SOIL

The soil has been removed from these roots to show how they penetrate it and prevent its being washed away.

Slopes from which the forests have been removed become an easy prey to the forces of erosion, and the soil which for thousands of years has been accumulating may be swept away by the rainfall of a few seasons, leaving the slopes bare of soil and devoid of vegetable life. Thus the sites of valuable forests, which by proper care might have been continual wealth producers, are rendered nearly profitless deserts.

Damage Caused by Removal of Forests 209

The delta of the Po is built up of soil washed down from a vastly greater area of upland. So rapidly does erosion go on in this upland, because of the cutting of old forests, that within a decade great areas of green slope are transformed into rocky hillsides.

But the damage caused by destruction of forests in the uplands does not end with stripping the slopes of soil.



A SLOPE THAT HAS BEEN STRIPPED OF ITS TREES

The fertile soil has been washed away.

The rain that was formerly retained by the roots and vegetation, so that it slowly crept downward into the valleys and streams, now runs off quickly, flooding the rivers and doing damage to regions at a distance. Streams which formerly varied but little in their volume during the entire year now become subject to great extremes of high and low water. This renders them less useful for manufacturing, commerce, and water supply, to say nothing of the frightful damage done each year by floods.

Reckless Waste.—Not only is the destruction of our forests a menace to agriculture and to river navigation, but it actually threatens our future lumber supply. A technical authority in the United States Department of Agriculture has estimated that if the present waste of our forest resources continues, there will not be left standing in the United States forty years from now a stick of timber



RECKLESS WASTE

The débris was left to feed the forest fires and all the standing timber was ruined.

fit for commercial purposes. When the importance of lumber to all kinds of industries is considered, such a possibility is appalling.

The newspapers are the greatest consumers of paper in the world. Since all the paper used by these great

institutions is from wood pulp, it may be safely said that the newspapers are the greatest users of forestry products in the world. If all the newspapers of the country should unite in demanding a sane national system of reforestation, the people could be aroused to action and this country, in fifty or sixty years, could be better supplied with lumber than any other first-class power in the world.



Courtesy American Forests and Forest Life
SAVING THE FORESTS

In a year waste-paper gatherers pay 50 million dollars for two million tons of waste-paper. This is equivalent to the pulp-yield from 300,000 forest acres.

Not only are forests being recklessly cut down, but forest fires are each year destroying timber worth millions of dollars. In Canada and in most European countries, citizens are taught more emphatically the necessity of fire prevention in forest areas. The contrast between the well-kept forests in Canada, especially in the region between Lake Superior and the Rockies, and the burnt-over wastes on the United States side of the border is

painful. We can well afford to spend as much money as Canada in providing for an efficient system of fighting (or still better, *preventing*) forest fires.

Oral Report.—Make a report on the citizen's duties in conserving forests. What are the laws of your state regarding conservation of forests? Is a legal permit to build a fire required of all campers in your state?

What precautions should be observed in the care of campfires? The Official Handbook of the Boy Scouts of America treats this subject rather fully.



GOOD FORESTRY

Notice how the underbrush and small timber has been cleaned up and gathered into piles to guard against fire.

The Necessity of Scientific Forestry.—No country can destroy its forests and remain in the first rank of nations. All the forests of eastern China were destroyed, root and branch, generations ago. Soil has been washed out from the uplands, terrible floods periodically visit the lowlands bringing death and destruction, and the peasants scour the fields for stalks of weeds to keep from freezing to

death. Much of the richest agricultural land of Spain has been ruined because of the destruction of protecting forests.

One hundred years ago, France faced much the same situation that America faces to-day. The French Government solved its problem by planting great tracts of shifting sands with trees. It is no exaggeration to say that the forests started in France one hundred years ago furnished the lumber without which Allied victory would not have been possible. There are in this country about eight million acres of cut-over forest lands, worthless for any agricultural purpose, that could be replanted to forests and made to produce all the lumber this country might ever need.

Within recent years the United States Government has established a number of forest preserves which are carefully patrolled. Here destruction from forest fires is rigidly guarded against. But to meet the future needs of this country, the forestry policy must be greatly broadened.

Every wise farmer practises forestry on a small scale. He plants his hillsides to meadow for grazing. He keeps his overflow land sowed to grass or hay, instead of exposing it by cultivation to the wash of the floods. He plants trees on rocky slopes or where the soil is of low grade. He



A FINE EXAMPLE OF SCIENTIFIC FORESTRY

cuts only his mature trees for use, and leaves the young trees standing to provide for future needs.

Reclaiming the Lowlands.—River-built lowlands have fine-textured soils and are very fertile. But bottom lands and flood plains are treacherous places because they are exposed to the overflowing of the river at time of flood.



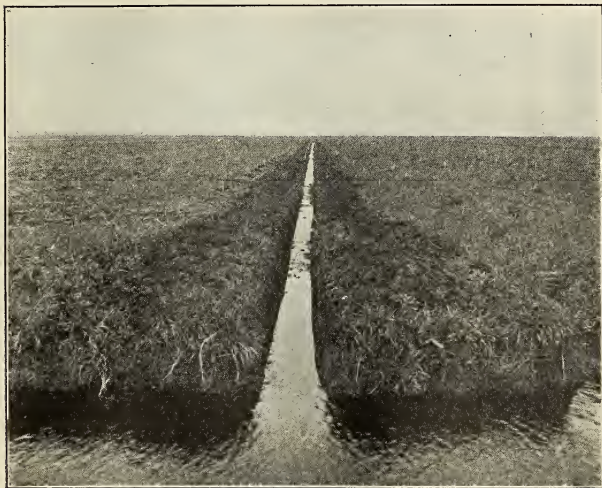
A CYPRESS SWAMP IN LOUISIANA BEFORE DRAINAGE

A floating dredge is used to cut a canal around the area to be reclaimed. The earth excavated from the canal is piled into an embankment inclosing the tract. In this tract a network of drainage canals and ditches is dredged from which the surface water is pumped out.

In some cases artificial levees, such as those along the lower Mississippi and the lower Sacramento, have been built to keep rivers from overflowing their flood plains. In many cases, such levees have not proved strong enough or high enough to avail against occasional overflows that demolish crops and sometimes ruin the very soil itself.

It is the work of the United States Reclamation Service, aided by the states interested, eventually to build up systems of levees that will provide for such valuable farm lands adequate protection against floods.

But this is not the only means of reclaiming lowlands. The establishment of reservoirs near the head waters

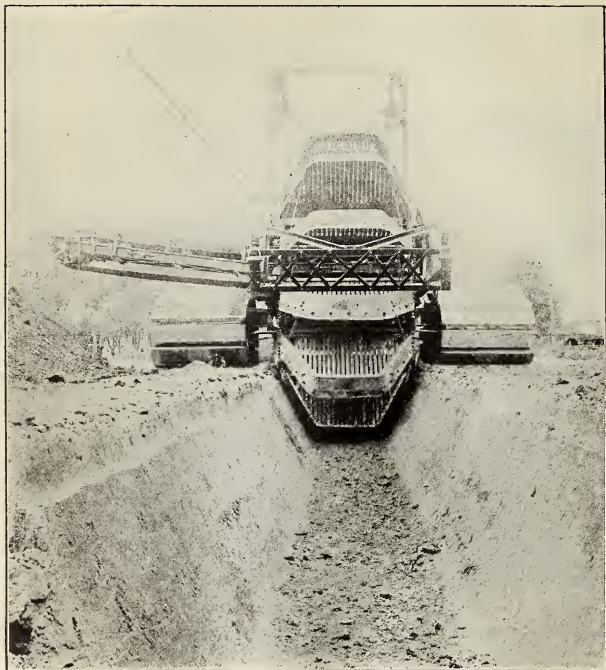


CYPRESS SWAMP RECLAIMED

This is the same section that was shown in the preceding illustration, after the land had been drained, cleared, and staked out for cultivation.

of rivers would do much not only to prevent destructive floods but also to even the flow of the river through the year. Very often such a reservoir may be constructed near the head waters of a stream, by damming the outlet of a lake. A tremendous reservoir of this kind could be built at the head waters of the Mississippi. Flood basins may also be established at advantageous places along the

river's course. Such reservoirs and flood basins would furnish farmers along the river with water for irrigation during the dry months that often succeed floods.



Courtesy The Buckeye Traction Ditcher Company

A TRACTION DITCHER

Digging a drainage ditch 12 feet wide at the top and 7 feet deep. In sixteen hours' time it will dig such a ditch as this 2000 feet long. Such a machine is indispensable in reclaiming large tracts of land by drainage.

Lands that have been reclaimed along the lower Mississippi and in the Everglades of Florida have proved very valuable. The Imperial Valley in southern California,

which lies in some places 250 feet below sea level, is developing into one of the greatest garden spots in the world. It will support a much larger population when ample storage reservoirs are provided in the uplands to supply water during years of drought, and flood basins have been established to take care of the surplus water in years of heavy rainfall.

IV. THE RAIN THAT SOAKS INTO THE GROUND

Evaporation.—Evaporation is constantly going on (page 165). The amount of water evaporated from the surfaces of lakes and of rivers, from the steam of factories and of locomotives, from the leaves of plants and from the skin of animals is tremendous. Even a part of the water that soaks into the soil may return gradually to the surface and be evaporated.

How Ground Water Returns to the Surface.—Experiment 75.—Place small glass tubes of several different bores upright in a dish of colored water. In which is the surface of the water higher, in the tubes or in the dish? In which tubes is it the higher, those of large or small bore?

Experiment 76.—Place two wide-mouth 4-oz. bottles side by side and fill one partly full of water. Put a coarse piece of cloth, or better, a lamp wick, into the water bottle and allow the other end to hang over into the empty bottle. (Figure 84.) Allow the bottles to stand thus for an hour. What happens?



FIGURE 84

The force that causes a liquid to rise up narrow tubes or wicks is called *capillary attraction*. The smaller the diameter of the tube the higher the water rises. This accounts for the rising of the liquid paraffin up the candle wick (page 96), explains why a blotter takes up ink, and why rough towels take up moisture more readily than smooth towels.

Capillary attraction in surface soil is very important. Dry surface soil acts like a blotter for moisture immediately underneath. If it were not for capillary attraction, all the moisture that sinks into the spongy earth would sink deep into the soil, leaving the surface as dry as the desert sands. Through capillary attraction, moisture necessary for plant life is drawn back toward the surface.

Evaporation is the source of all the moisture which falls as rain and three-fourths of all evaporation takes place at the ocean surfaces.

The Earth's Crust like a Giant Sponge.—Experiment 77.—Weigh carefully a piece of dry coarse sandstone or coquina. Allow this to remain in water for several days. Wipe dry and weigh again. Why has there been a change in weight?

Of the water that sinks into the soil and does not return to the surface by capillarity, part finds its way into springs, and part sinks deep into the soil and rock. Gravity is continually pulling the soil water deeper and deeper into the ground.

The earth's crust is made up of layers of different materials. For example, in the lowlands a layer of black soil may be underlaid with layers of yellow clay, sand, blue clay, gravel, limestone, sandstone, etc. In the uplands, a thin layer of soil may be underlaid with layer after layer of rock. Scarcely any rock is impervious to water. Even massive granite contains water in its minute pores.

But of course some substances are so much less porous than others that water seeps very, very slowly into or through them. Such layers we regard as impervious to water. Granite is so slow to absorb water or to allow it to pass through that we think of it as one of the most impervious rocks. Fine clay and limestone absorb water but do not allow it to pass through them readily. Coarse

soil, sands, and sandstone do not absorb water so readily but they allow it to pass through readily.

For millions and millions of years, rains have been falling and moisture has been soaking down through the layers until the outside layers of the earth's crust are in most places pretty well saturated. Of course, on account of the earth's internal heat and pressure, there must be a

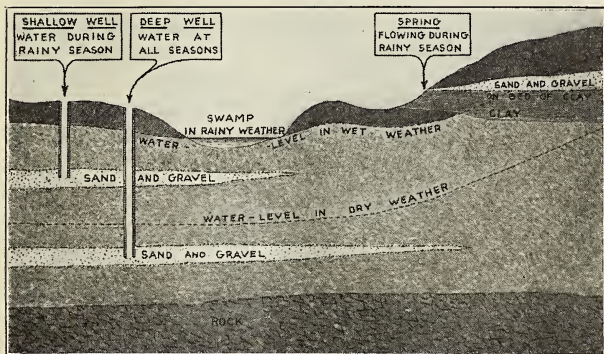


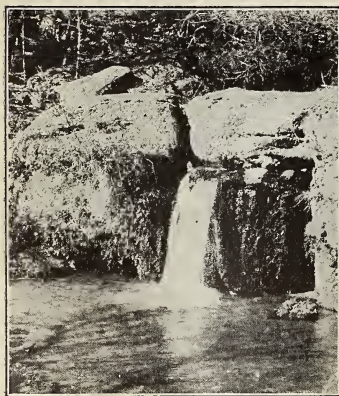
FIGURE 85.—DIAGRAM ILLUSTRATING LEVEL OF WATER-TABLE IN WET WEATHER AND IN DRY WEATHER

limit to which water may sink. But man has not been able to penetrate the crust of the earth to a depth where there is not water. It has been estimated that the amount of water that exists in the rocky crust of the earth would make an ocean of water 800 feet deep extending over the whole earth.

The Water-Table.—During rainy seasons, the soil in low places may be saturated to the very surface; that is, all the spaces between particles of soil are filled with water. Most of the time, however, the spaces between soil particles at or near the surface are not filled with water.

But if we dig deeply enough we come to a level where the water is so abundant that all spaces between soil particles are completely filled with water.

The level at which this free ground water stands below the surface is called the *water-table*. The water-table does not remain at any particular depth underground but rises or falls as the seasons are rainy or dry. (Figure 85.) The word level as applied to the water-table is somewhat misleading, because the water-table is not like the surface of a lake. It follows more or less the contour of the ground above.



A NATURAL SPRING

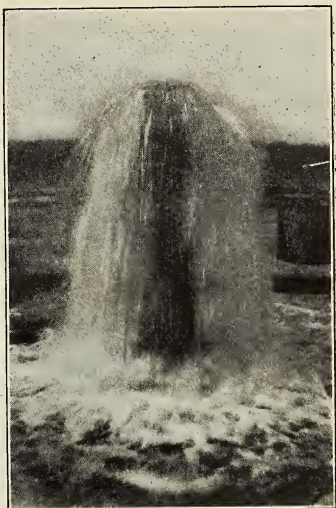
Coming to the surface between rock layers.

It is practically level under level ground, curves upward under hills, and bends downward under depressions. The water-table may be very close to the surface in low rainy districts, or from 2000 to 3000 feet below the surface in rainless plateaus.

Wells and Springs.—Some people have a mistaken notion that when we dig a well, we dig until we come to an “underground stream.”

Underground streams are very rare and are seldom if ever sources of well-water supply. Most shallow wells are simply dug to extend below the water-table. (Figure 85.) Generally an attempt is made to reach a layer of gravel under the water-table as the bottom of a good well. It is because the water-table is so deep in rainless plateaus that wells are impracticable in those regions.

From the banks of creeks or rivers, from the sides or from the base of deep gullies, or from canyon walls springs occasionally flow. Such springs generally originate in a porous layer, such as gravel, sand, or sandstone, which is underlaid with a less porous layer, such as fine clay or limestone. Because the water seeps so slowly through the compact under layer, it collects in the porous layer. If this porous layer comes to the surface, the water trickles out in the form of a spring. In the lowlands, a long period of drought may lower the water-table so much that it falls below the bottom of a well or a porous layer in which a spring originates. Such a well or spring then "dries up" temporarily. (Figure 85.)



FLOWING ARTESIAN WELL

Artesian Wells.—Sometimes the wrinkling of the earth's crust has folded rock layers so that their edges come to the surface at some high altitude. (Figure 86.) If one of these layers (c) is porous, the ground water will sink into it and saturate the entire layer. If this porous layer,

usually sandstone, lies between two layers that are impervious, the water at the lower levels



FIGURE 86

of the porous layer will be under pressure of the entire weight of water above it. If a hole (w) be drilled through the upper impervious layer of rock the water will flow to the surface. If the pressure is great enough the water will gush out of the hole.

Borings of this kind form *artesian wells*. This water is free from surface contamination and is usually, therefore, healthful for drinking. In one section of South Dakota there are over a thousand wells, some of them yielding as much as 1000 to 2000 gallons a minute. The low-lying



HOT SPRINGS IN THE YELLOWSTONE NATIONAL PARK, U. S. A.

coastal plains are often abundantly supplied with artesian water. Southern New Jersey, Delaware, and Maryland are fortunate in this respect.

Hot Springs.—Hot springs in volcanic regions may derive their heat from hot lava layers not far below the surface. Hot springs that occur away from volcanic regions are generally of deep origin. Water has sunk to a great depth, probably about 4000 feet. Here the internal heat of the earth's crust has raised the water to such a temperature that it may be forced to the surface again

under terrific pressure. We have seen how the water that goes still deeper and is absorbed by the heated rocks sometimes returns to the surface as the steam of volcanoes.

Why Underground Waters Are Clear.—Experiment 78.—

Procure a three pound coffee can or a cheap metal pail. With a nail punch a dozen holes in the bottom of it. At the bottom of the can put *coarse* clean gravel to the depth of an inch. On top of this put an inch or more of *fine* clean gravel, and over this about four to six inches of clean sand. *Be sure that the gravel and sand are washed clean.* Set the can above a clean bowl or bucket.

Make a mixture of fine soil and water. Pour the murky mixture gently on to the surface of the sand in the coffee can and observe the water that falls into the bowl underneath. Is it still murky or is it clear?

When dirty surface water seeps down through thick enough beds of sand and porous rock, it is cleansed of its dirt; but it does not lose by this filtering process any of the substances it held in solution. On the contrary, *it may have dissolved substances from the rocks through which it filtered.*

V. WATER AS A SOLVENT

Greatest of all Solvents.—Experiment 79.—Put a little salt into water in a clean beaker or drinking glass, and stir. The solid entirely disappears. Taste the water. Has the salt affected the water in any way? Pour out three-fourths of the water and taste again. Is there any difference between the saltiness of the upper portion and the lower portion of the water?

Experiment 80.—(Teacher's Demonstration.)—Fill a tall bottle with water colored with blue litmus. By means of a long thistle tube, slowly pour a little sulphuric acid into the bottom of the bottle (Figure 87). Allow the bottle to stand undisturbed and note the gradual change in color of the litmus, showing that the heavier acid is mixing, or *diffusing*, upward through the water.



FIGURE 87

Water is the greatest of all solvents. It dissolves to a greater or less extent almost all

substances with which it comes in contact. There is probably no water on the surface of the earth which is absolutely pure. All ordinary water has come in contact with some substances which it could dissolve.

Experiments 79 and 80 show that when substances are dissolved in water they tend to mix thoroughly with the water and to produce a uniform solution. When we mix water, lemon juice, and sugar together to make lemonade, the solution has a uniform taste throughout. Neither the solid nor the liquid tend to separate out of the solution nor to accumulate in any one part of it. As a result of this characteristic of solutions, the water of the whole ocean from top to bottom is practically uniform in composition.



FIGURE 88

How Water Is Purified—Distillation.

—**Experiment 81.**—Into a glass of clear water stir a half teaspoonful each of sand and fine dust. Add some salt to the contents of the glass. Arrange a glass funnel with a filter paper in it, as shown in Figure 88. Pour the contents of the glass into the funnel and collect the water that runs through the filter paper. Do the sand and dust run through? Put a little of the filtered water in a watch crystal or in a shallow vessel and allow it to evaporate. Did the salt in solution come through the filter paper?

Experiment 82.—(Teacher's Demonstration.)—Fit a flask with a one-hole stopper. Bend a piece of glass tubing as indicated in Figure 89. Fit the short arm of the tubing into the hole of the rubber stopper so that the end of the tubing shall not extend below the bottom of the stopper. Insert the long arm of the tubing into an open test tube surrounded by cold water or chopped ice.

Put a teaspoonful of salt, a like amount of garden soil and

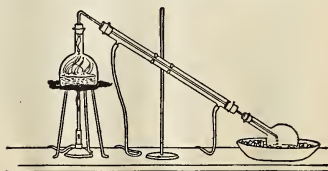


FIGURE 89

a few crystals of potassium permanganate into a glass of water. Mix well. Pour the mixture into the flask, insert the stopper securely, and put the flask over a slow flame. Bring the mixture to a boil and let it simmer slowly.

When about an inch of water has collected in the test tube, turn off the heat. Is the water clear? Taste it. Has it lost its saltiness?

This process is called *distillation*. Review Experiments 56, 57, and 58. This review shows you that distillation is simply a combination of evaporation and condensation. The water in the flask is rapidly evaporated by the heat and the vapor is condensed by cooling in the test tube.

Experiment 78 shows that when water is filtered, the solids *suspended* in it are removed, but Experiment 81 shows that filtration of water does not remove substances that are *dissolved* in it. In distillation the vapor passes off, leaving both the suspended and dissolved solids behind. Evaporation and condensation are constantly going on in nature. And so the water which evaporates from the surfaces of lakes and rivers to condense and fall as rain, goes through a process of purification by natural distillation.

Salt Water and Fresh Water.—Experiment 83.—If ocean water can be obtained, boil down about a pint of it in an open dish. Taste the residue. What is the principal constituent of this residue?

Ocean water has about $3\frac{1}{2}$ pounds of solids dissolved in every hundred pounds of water—about $\frac{1}{2}$ ounce of solids to the pint. There are solids dissolved in river and lake water too, but the solids dissolved in sea water are two hundred times as abundant as in the “fresh” water of lakes and rivers. When the river waters run into the sea, they carry with them whatever they have dissolved from the land. When the water of the sea evaporates and is borne away, to fall upon the land again, the dissolved material is left behind in the ocean.

In some inland regions the rainfall is so small that the lakes never fill up sufficiently to overflow their rims. The water is evaporated from the surface as fast as it runs into the lake. Thus all the salt and other soluble substances which have been extracted from the land and brought into the lake by the rivers remain there, since only pure water is evaporated. In this way a lake which has no outlet becomes salt. Great Salt Lake in Utah is an example of this. Some salt lakes, like the Caspian Sea, were probably once a part of the ocean, so that they have always been salt.

Water Dissolves Air and Other Gases.—Experiment 84.

—Fill a small beaker with fresh water. Heat it slowly. Bubbles collect on the bottom and sides. When the water becomes cold these bubbles do not disappear immediately. If these were bubbles of water vapor they would condense to water when the temperature was lowered. What are they? Where did they come from?

We have learned that all air has water vapor diffused through it. Experiment 84 showed that there was also air in water. All water exposed to air has air dissolved in it. It is upon this air in solution that fishes depend for the oxygen they need. But while air may hold moisture, and water may hold air, Experiments 57 and 84 show an important point of difference between the capacity of air for water and of water for air. We learned that when air is heated it is capable of holding more water vapor. But when water is heated, it is capable of holding less air.

Water has the ability to absorb other gases, such as carbon dioxide and ammonia gas.

How Water Hollows Underground Caverns out of Rock.—Experiment 85.—(Teacher's Demonstration.)—Prepare carbon dioxide as in Experiment 27. Instead of collecting the gas in bottles, put the delivery tube into a test tube half filled with limewater. Let the delivery tube extend to the bottom of the test tube so that

How Hard Water Builds Columns of Rock 227

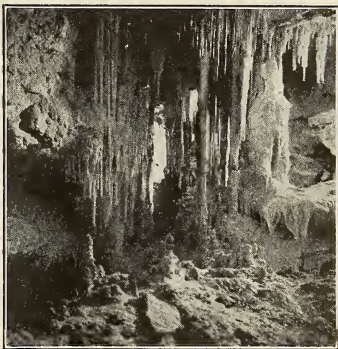
the carbon dioxide will bubble up through the limewater. Does the limewater take on a milky appearance? The carbon dioxide has changed the limewater compound to water and "limestone."

Take the delivery tube out and allow the chalky material to settle or "precipitate." When it has precipitated, close the mouth of the test tube and shake the contents of the tube vigorously. Does the water dissolve the limestone?

Now allow the carbon dioxide to bubble through the water again.. Does the water eventually become clear? (Save the water in the test tube for the next experiment.)

When water has absorbed carbon dioxide it is able to dissolve limestone and it then becomes hard. In this way "soft" rain water may become hard water or mineral water before it reaches the surface again in springs or wells.

In some places the surface water penetrates into layers of rock which it can dissolve, such as salt or limestone. Here it forms caves and caverns. There are thousands of caves of this kind, but perhaps the most noted in this country is Mammoth Cave with its nearly 200 miles of underground avenues and grotesquely sculptured halls.



A LIMESTONE CAVE

A cavern dissolved out by water. Hard water trickling in and evaporating has formed the columns.

How Hard Water Builds Columns of Rock.—Experiment 86.—Put the hard water resulting from the preceding experiment into a small container and slowly boil the water away. Is there a trace of the "limestone" left in the container?

When water which has dissolved limestone is evaporated, the limestone remains. A glance at the inside of a tea kettle in which hard water has been boiled shows the deposit of limestone. Boiling, as well as evaporation, causes this substance to deposit. When the water is boiled, the carbon dioxide is driven off, and so the water is no longer able to hold the limestone in solution.

In underground limestone caves beautiful rock columns are frequently formed. Hard water trickles in from the layers above and evaporates. The limestone that was dissolved in the water is thus left on the roof of the cave. Drop by drop as the water evaporates, a column grows downward from the roof like an icicle. The drops that fall to the floor and evaporate build a corresponding pillar up from the floor. Eventually the two meet, forming a solid column.

SUMMARY

Pure water is a colorless, odorless, tasteless liquid. Until 1784 water was believed to be an element. Sir Henry Cavendish, an English scientist, discovered that each molecule of water is made up of two atoms of hydrogen and one of oxygen. Although the hydrogen makes up two-thirds the volume of water, oxygen makes up eight-ninths of its weight. No substance equals water as a carrier of heat. When water solidifies into ice, it expands with such tremendous force that it exerts a pressure of more than 100 tons to the square foot.

Running water is the chief tool which has carved the features of the earth. The more violent the motion of water, the greater is its sculpturing work. Streams and rivers have sculptured the highlands of the earth into mountain peaks, and have carried the wreckage down to fill the valleys. This sculpturing effect of water in motion is called "water erosion." Materials that are washed

down from the highlands serve to build up the lowlands and to fill in water areas, thus adding to the habitable surface of the earth. The work done by waves in wearing away the land and distributing the waste is next in importance to that of running water. In many cases, too, the waves use this very same material that has been pilaged from the land to build up land areas in other places.

The cutting away of trees in the uplands leaves the slopes an easy prey to water erosion. In order to prevent the washing away of soil which has been accumulating for thousands of years, and to prevent disastrous floods, it has been found necessary to reforest the exposed slopes. Scientific forestry has also become a necessity because we must provide for the country's future lumber supplies. The United States Government has found it profitable to coöperate with the states in the reclamation of lowlands by expensive systems of drainage.

The earth's crust is like a giant sponge. The water that sinks into the soil has permeated to some degree every substance in the earth's crust. Man has not been able to penetrate to a depth where there is not water. The level at which free ground water stands below the surface is called the "water-table." Wells and springs do not originate in underground streams. They have their origin in the free water that lies below the level of the water-table. Artesian wells are found in the lowlands. Their origin lies in the uplands. The water has saturated an exposed porous layer which lies between two impervious layers of rock. When the upper of these impervious layers is drilled, water flows to the surface. Hot springs derive their heat from hot lava layers or from heated rocks that lie at great depths. Underground water is clear because it has been filtered through beds of sand and porous rock.

Water is the greatest of all solvents. The only sure way to relieve water of all substances that are dissolved

by it is to distill it. The reason why the water of the ocean and of certain lakes is salty is because the rivers have carried to the sea the substances dissolved from the land. The water of the sea evaporates, and the dissolved materials are left behind. The higher the temperature of the water, the less air but the more solid material it will hold in solution. Water, by its ability to dissolve substances, hollows underground caverns out of rock. The evaporation of water that has dissolved limestone is responsible for the building of beautiful rock columns in underground caves.

QUESTIONS

Of what elements is water composed?

For how much of the volume of water is each element responsible?

For how much of the weight?

Why is water such an effective carrier of heat?

Why does water exert such force when it freezes?

How have water and heat been jointly responsible for sculpturing the crust of the earth?

Upon what does the carrying power of water depend?

How do rivers act as destroyers? In what way do they serve as builders?

How do waves act as destroyers? How do they serve as builders?

What are the advantages of protecting the upland soils with forests?

What dangers lie in reckless waste of lumber?

What is scientific forestry?

What are some of the means used by governmental agencies of reclaiming lowlands?

How does ground water that has been absorbed by the soil rise again to the surface?

Do wells and springs originate in underground streams? If not, describe their origin.

What is the origin of artesian wells? Of hot springs?

Why are underground waters generally clear?

What is distillation?

Why is the ocean and why are certain great lakes salty?

What relation is there between the temperature of water and its ability to dissolve air?

How does water hollow underground caverns out of rock?

How does water build columns of rock in underground caverns?

CHAPTER X

WATER AS THE SERVANT OF MAN

Fire and water are faithful servants but cruel masters.—Old Proverb.

In the preceding chapter we have discussed certain characteristics of water and have seen some of the work it does in our natural surroundings. Water is and always has been essential to man, but within the last century it has been made to serve him in many ways previously unknown. Modern methods of supplying water have done away with much disease. Adequate water supply and modern methods of cleansing have started modern man on the trail to real comfort and health. Artificial ice and cold storage have simplified the problem of food storage.

The harnessing of steam has revolutionized industry and transportation. The nation is waking to the necessity of using its inland waterways to supplement railway transportation. The power of rivers and waterfalls is being conserved, and within the next fifty years running water will be made to do much of the nation's work.

I. MODERN METHODS OF SUPPLYING WATER

Primitive Methods.—Primitive man was dependent on streams and flowing springs for his water supply. In Oriental countries women still go, just as the women of 3000 years ago went, to wells, streams or lakes for the day's water supply. Indians in the semi-arid regions of

the West still depend on water-holes to preserve water in time of rain. These water-holes are generally so situated that a large surface drains into them.

In many backward countries, water is peddled from door to door in water carts, goat-skin bags, or earthenware jugs. In such countries, the peddled water is too ex-



A PRIMITIVE WATER CARRIER IN MEXICO

pensive for cleansing purposes. Clothing is carried to the streams and washed in the water that is often afterward peddled for drinking. Bathing could hardly become a habit under such conditions, and housecleaning is unknown. The use of polluted water for drinking and the lack of an adequate supply for cleansing purposes make such countries the centers of plague and pestilence.

Rural Water Supply.

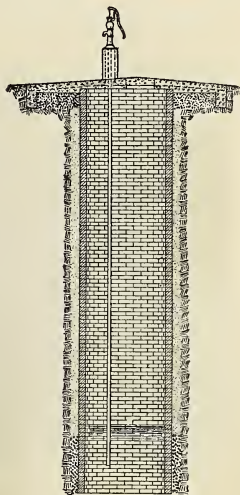
—The great majority of our people on farms and

in small communities are dependent on shallow wells for their water supply. A Government authority on the health of rural communities has said that most users of well water know nothing about their own particular supply beyond the fact that it is usually clear, palatable, and wet.

Careless location and construction of wells often result in contaminated waters that breed disease. Many wells are simply bricked up loosely to prevent them from caving

in. The walls of a well should be cemented water tight and the shaft should be built above the surface to prevent the contaminated surface water from flowing directly into the well. (Figure 90)

Great care should be taken in villages to keep the streets and backyards free of refuse or filth of any sort. Stables and outbuildings on farms should be far enough away from the well to prevent the polluted water from seeping into the water supply. (Figure 91.) If such buildings can be located at points lower than the well, so much the better. Surface water must seep through at least a hundred feet of close-packed soil—and farther through very porous substances—before it is freed of its contamination. This does not mean that the well should be one hundred feet deep; but it does mean that all sources of contamination should be much more than one hundred feet from a well and never at points higher than the well.



Courtesy U. S. Dept. of Agriculture.

FIGURE 90.—PROPERLY CONSTRUCTED WELL

Supplying Water to Populous Communities.—The supplying of water to large communities has always been one of man's great problems. Rome received its water supply by aqueducts from nineteen different sources, and some of these aqueducts were in use for fifteen centuries. The ruins of aqueducts built by the Romans are to-day among the most picturesque sights of the Italian and Spanish landscapes. Eighteen great water cisterns, remarkably well preserved

are the only remains of the once thriving city of Carthage on the North African coast. Near Tunis may be seen a stretch of the ancient aqueduct that brought water to these cisterns from the mountains thirty-five or forty miles to the south.

Only in recent times have deep wells been sunk and

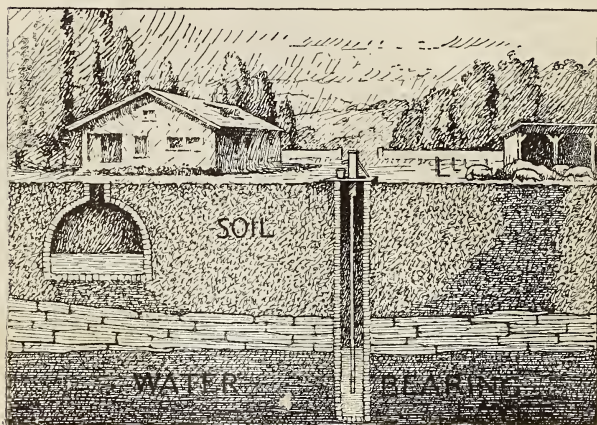


FIGURE 91.—A WELL WITH CONTAMINATED WATER SUPPLY

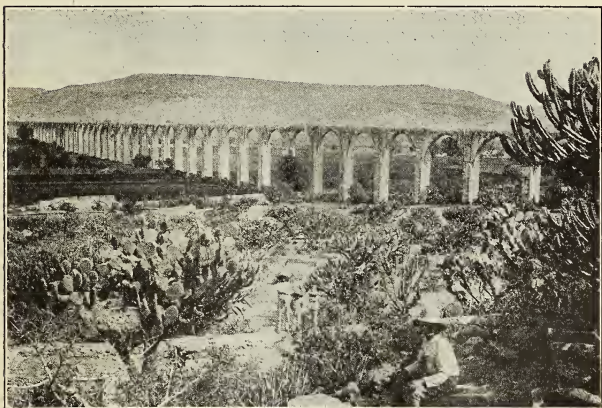
water lifted from great depths. Modern large cities have seldom found supplies of water from underground sources adequate to the demands of manufacturing and sanitation, although for many years London and Paris obtained a considerable part of their water supply from these sources.

Most of the great cities of the world are largely if not wholly dependent on near-by rivers and lakes for the water they use.

The Great Lakes serve as natural storage basins for Chicago, Cleveland, Buffalo, and other cities in that region. Saint Louis, Cincinnati, and many other cities depend on

the great rivers to deliver them a constant water supply. But the larger coast and mountain cities have been turning one by one to the hills and mountains for their pure water supplies. They have conserved the uncontaminated waters of the uplands in huge reservoirs and have constructed great pipe lines to conduct the pure water to the cities' mains.

The experience of New York City in providing water for



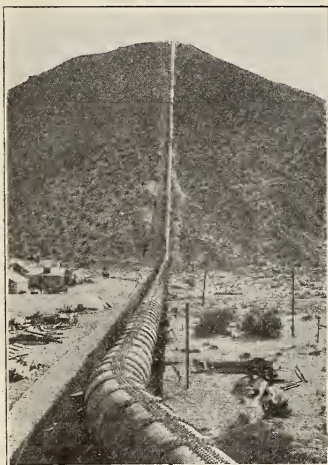
AQUEDUCT IN USE AT QUERETARO, MEXICO

an ever-increasing population shows how great the problem may be. In 1843 the city finished a dam across the Croton River just a few miles above the point where the river enters the Hudson. The artificial lake thus formed had a capacity of a billion gallons. The Croton Aqueduct was built at tremendous cost to convey the water to the city from the Croton reservoir forty miles away.

In less than fifty years the needs of the city had grown so tremendously that it became necessary to build a larger

dam. This dam at the time it was built was second only to the Pyramids of Egypt in the number of cubic yards of masonry in its make-up. The capacity of the lake thus formed by the new dam was thirty-two billion gallons of water.

Within recent years New York has again been compelled to increase its water supply. To do this, the city purchased nine hundred square miles of mountain land in the



AN INVERTED SIPHON IN THE PIPE LINE FROM
THE MOUNTAINS TO LOS ANGELES

Catskills. It is estimated that the total storage capacity of this new reservoir is 120 billion gallons of water, and it is capable of furnishing to the city a steady supply of one billion gallons a day.

An aqueduct 130 miles long, capable of delivering a half billion gallons of water a day, conducts these Catskill waters to the city's mains. This aqueduct crosses valleys fourteen times by means of inverted siphons, and pierces mountains in tunnels twenty-four times.

Where it crosses the Hudson River, the aqueduct drops vertically to a depth 1100 feet below sea-level, passes through solid rock and rises vertically on the other side. In the city the aqueduct divides into a series of tunnels through solid rock several hundred feet below the streets, with shafts rising vertically to connect with the cities' mains.

The construction of the Catskill water supply system

was a greater and more complicated engineering feat than the digging of the Panama Canal.

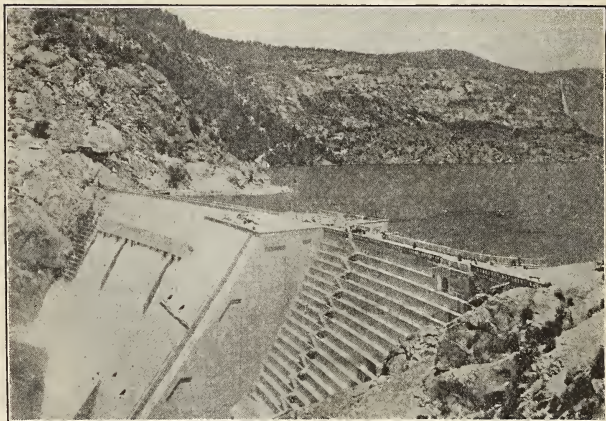
Los Angeles took advantage of a natural reservoir in the high Sierras. It constructed dams to increase the capacity of this reservoir. But this water supply was 242 miles away! The city undertook and completed the prodigious task of building the longest aqueduct in the world. This tremendous iron pipe conveys the water 242 miles over foothills and through canyons to the city's mains. Thus the city is furnished with an abundant supply of pure water from the uncontaminated uplands.

This reservoir is capable of supplying the needs of a population of 2,000,000 people. But although this water system is only a few years old, it is already inadequate. Plans are now under way for the establishment of a reservoir on the Colorado River, 270 miles away. This reservoir will provide for the needs of from $7\frac{1}{2}$ to 10 million people in Los Angeles and other municipalities of southern California. The water from this reservoir will have to be pumped to the crest of an intervening mountain range, from which it will flow by gravity to many cities.

The metropolitan water district of Boston has one of the largest and best water systems in the world. It draws its supply from the great Wachusett reservoir built by the city at great expense in the hills of Worcester County. The water supply of Portland, Oregon, comes from a natural reservoir that collects the melting snows of Mount Hood. The water of this well-guarded reservoir is not only pure and cold, but is as soft as rain water. San Francisco will soon have a pure and abundant water supply drawn about 200 miles from the uncontaminated uplands of the Hetch-Hetchy Valley.

The Vital Importance of Pure Water.—Roman and Greek writers more than two thousand years ago empha-

sized the advantages of a *pure* water supply to a city. It is now generally recognized that a modern city has no task more vital than that of guarding against contaminated water. Those communities that use polluted water generally have a very high death rate from typhoid fever and from other intestinal diseases. Moreover the industrial

*Wide World Photo*

HETCH-HETCHY DAM

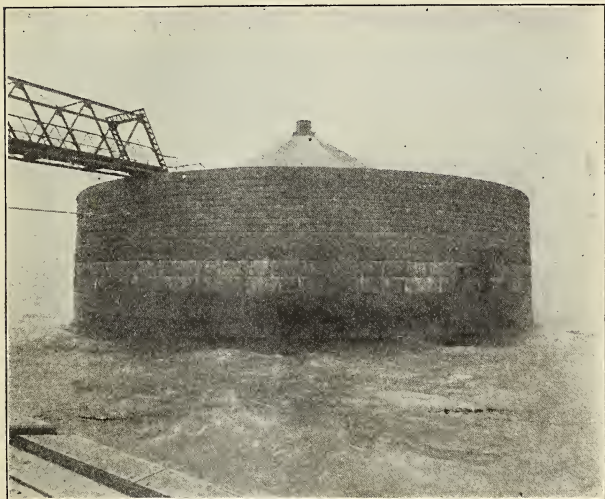
Source of San Francisco's future water supply. A twelve-mile lake has been created by damming the Tuolumne River.

efficiency of a population is greatly reduced by sickness. Cities that receive their water supplies from uncontaminated uplands have a tremendous advantage.

All cities with upland reservoirs keep them constantly guarded against pollution. They take great pains to control the entire area that contributes drainage to their supply basins. A dozen villages had to be abandoned in order to protect the Catskill reservoirs of New York City. Thus the task of providing pure water from upland reser-

voirs is less difficult because the sources of drainage are always under control.

Cities along the Great Lakes have run pipes out for miles to intakes, or *cribs*, in order to avoid shore contamination.

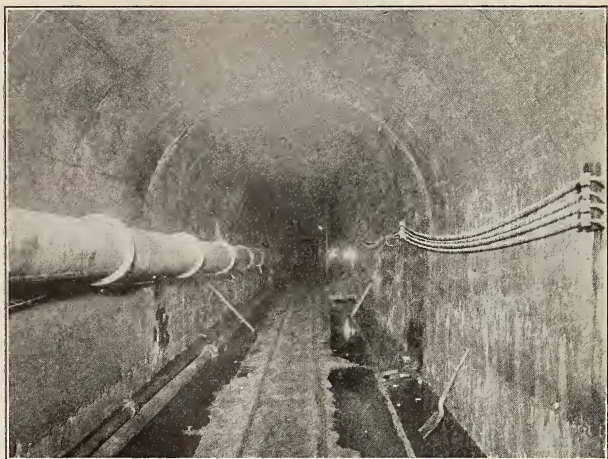


ONE OF THE CHICAGO INTAKE CRIBS

In time of heavy storms, the sewage from a city sometimes contaminates the water even at these distant intakes; but on the whole the supply of water to Great Lakes cities is good.

The Health Department in each of the cities supplied by the Great Lakes makes daily tests of the water and sees that it is kept free from disease germs. The amount of liquid chlorine necessary to exterminate disease germs differs with the seasons and with the conditions of the water. If even a few cases of typhoid or other intestinal diseases appear in a city, the Health Department

immediately publishes in all newspapers warnings to boil all drinking water until the source of infection can be found. Seldom is any such infection traceable to the city's supply of drinking water. So careful is the daily watch kept by Departments of Health that the people of the



WILSON AVENUE WATER TUNNEL, CHICAGO

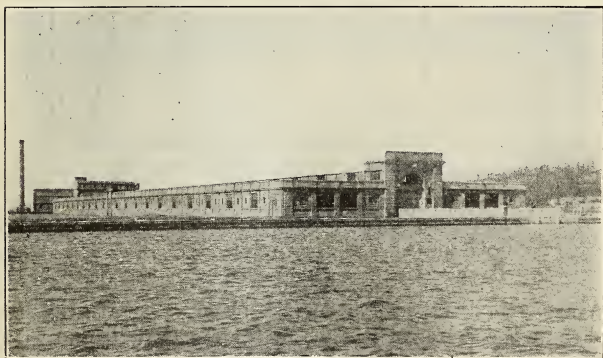
Photographed during construction. This tunnel is 12 feet in diameter, is hollowed out of solid rock 110 feet below the surface of the water, and extends eight miles from the pumping station on the north shore to the crib.

Great Lakes cities are practically free from the fear of polluted water. Water drunk by summer vacationists in certain camps and resorts is responsible for much of the intestinal infection that prevails in the cities in autumn.

Those cities which receive water from rivers that are constantly being polluted by the sewage of communities farther upstream have a most serious problem, even though running water tends somewhat to purify itself. In many cases this problem has been admirably solved.

The Delivery of Water Through Cities 241

St. Louis, for example, is typical of many cities that perform marvels in transforming muddy river water into clear, healthful drinking water. The Missouri-Mississippi water as it enters the St. Louis intake contains mud and sand in suspension; coloring matter from decaying leaves, as well as mineral matter, in solution; and disease bacteria. As the water passes slowly through settling tanks the heavier sediment falls to the bottom of the tanks. Chemicals are



ST. LOUIS FILTER PLANT

This building of reinforced concrete is 750 feet long by 135 feet wide.

added. Some of these unite with the coloring matter, and others with some of the mineral matter, forming chemical compounds that are not soluble in water. These compounds may fall to the bottom of settling tanks or may be removed by filtering through thick beds of sand and gravel. Finally small amounts of chemicals are added to kill the harmful bacteria, and the pure water is forced through the mains. None of the chemicals used makes the water harmful to drink or unpalatable to the taste.

How Water Is Delivered Through Cities.—Ancient cities had not the advantages of modern pressure pumps. They

were, therefore, dependent upon gravity to bring water to them from sources higher than the community served.

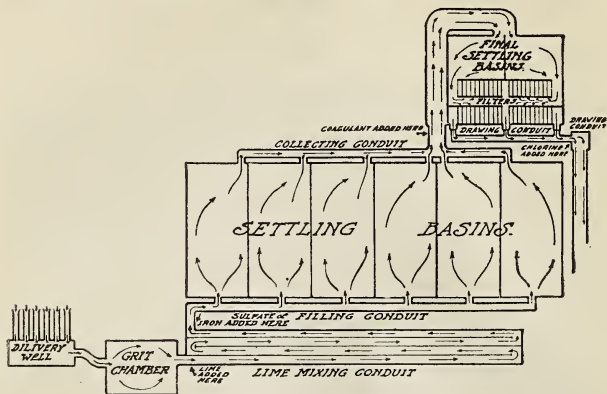


DIAGRAM SHOWING ST. LOUIS WATER PURIFYING PROCESS

The arrows show the course of the water through the plant.

Whenever possible, modern cities obtain their water supplies by the same method. But the modern city must do more than merely obtain water; it must deliver the water to every part of the city and to the top floors of the tallest buildings.

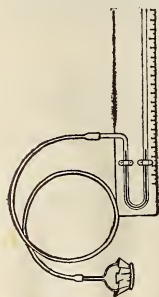


FIGURE 92

Pressure in Water.—Experiment 87.—Tie a piece of thin sheet rubber (dentist's rubber) tightly over the mouth of a small, short thistle tube. Attach tightly to the neck of the thistle tube a flexible rubber tube about two feet long. Bend a glass tube into the shape of a U, making one arm slightly longer than the other. Put colored water into the U-tube until it stands about two inches high in each arm of the tube. Fasten a

meter stick in a perpendicular position and tie the U-tube to it so that the long arm lies along the scale. Attach the open end of the

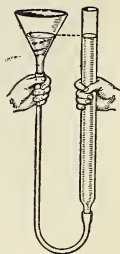
rubber tube to the short arm of the U-tube. When you press on the rubber sheet at the mouth of the thistle tube, the water rises in the long arm of the U-tube. You have made a simple pressure gauge. (Figure 92.)

Nearly fill a battery jar with water. Slowly push the thistle tube down into the water and notice the action of the column of water in the U-tube. How does increasing depth affect pressure? Being careful to keep the center of the rubber diaphragm at the same depth, face it up, down, and sideways. Does the pressure in different directions vary at the same depth? Hold the thistle tube at equal depth in the battery jar and in a pail or tub of water. Does the greater volume of water in the pail make any difference in the pressure at the same depth?

Since water has weight, it must exert pressure on whatever surface it rests on. Because water is a liquid and its molecules are free to move, this pressure is exerted in every direction, just as in the case of air (p. 178). A cubic foot of water weighs $62\frac{1}{2}$ pounds. The pressure on a square foot of surface at a depth of one foot is, therefore, $62\frac{1}{2}$ pounds. To obtain the pressure at the depth of 100 feet, all we have to do is to multiply $62\frac{1}{2}$ by 100.

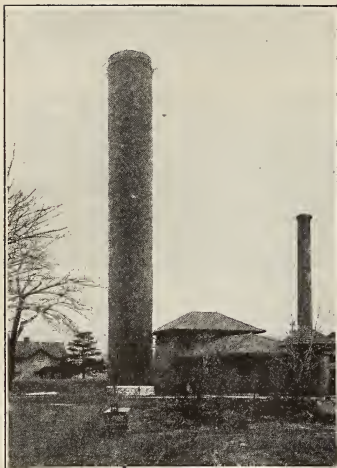
At a given depth the volume of the water makes no difference with the pressure. The pressure would be no greater six inches below the surface of a lake than at the same depth in the battery jar. For that reason, the pressure on a water main issuing from the bottom of a standpipe would be just as great as from a reservoir of great area, provided the depth of water in each is the same.

Where cities obtain water from low levels they are compelled to use pumps, or pumps combined with standpipes or elevated reservoirs. The pressure of the water in these standpipes or reservoirs forces the water to faucets through-



“WATER SEEKS
ITS LEVEL”

Water rises in the glass tube to the level of the water in the funnel.

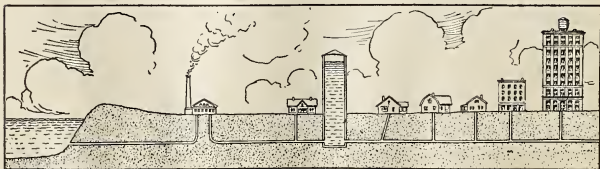


A STANDPIPE

This towers above every building in the district it supplies and furnishes water under high pressure to the entire community.

out the city. The higher the surface of the water is above the outlets, the greater will be the pressure. Largely on this account water from a standpipe or elevated reservoir has a weaker flow from faucets on upper floors than from those on lower floors of the same building.

The necessity of furnishing water to the top floors of very tall buildings and of fighting fire in these structures has compelled large cities to provide high-pressure pumps in addition to reservoirs. These pumps sometimes keep the water in the mains of the business sections at a pressure of 300 pounds, or even more, to the square inch.

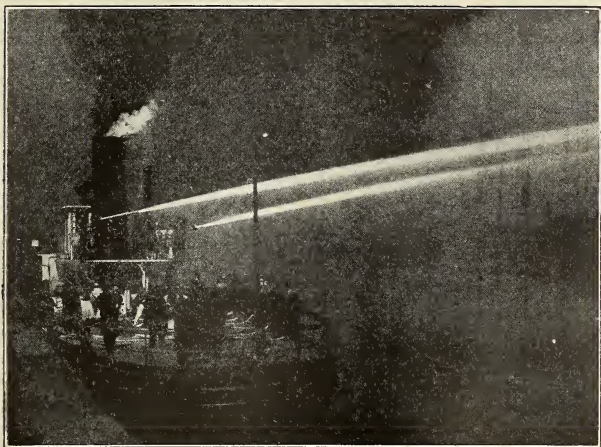


"WATER SEEKS ITS LEVEL"

The water in the standpipe tends to rise in any pipe through which it flows to the level of the water in the standpipe. The top floors of the tall building are above the water level of the standpipe. In such a case water from the city mains is generally pumped to a tank on top of the tall building from which it flows to the floors below.

Portland, Oregon, has the advantage of a mountain reservoir so high above the city that the force of gravity alone is sufficient to distribute water through miles of mains and to protect the tallest buildings from fire.

Water from the Catskill system of New York City is also distributed by gravity to all but the highest buildings



FIRE-TUG IN ACTION

The "Graeme Stewart" on the Chicago River, throwing streams of water under tremendous pressure.

of the city. To the top floors of buildings more than 300 feet high, water is pumped by power plants belonging to the buildings.

Almost every one has noticed how the opening of a faucet in a home will reduce the force of the stream from a garden hose. This illustrates what may happen on a larger scale throughout a city system. The larger the number of faucets running at one time, the lower the pressure. For this reason, most cities try to prevent

unnecessary use of water in homes during hours when business districts must be served and protected against possible fires. This is why many cities forbid the sprinkling of lawns during the busy hours of the day.

II. WATER IN THE HOME

Voluntary Project 1.—To study the plumbing.—Note to the Teacher: This may be made a class project if the school building is supplied by plumbing with hot and cold water.

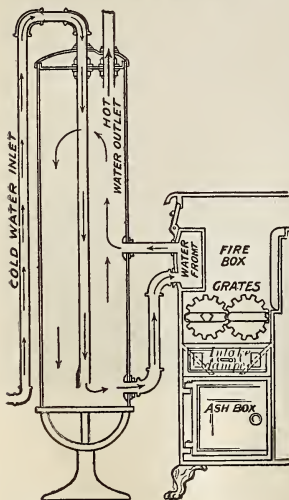


FIGURE 93.—HOT-WATER TANK

The school janitor or the school engineer will probably help guide the class through the mazes of the basement. After the pupil has been conducted through the school building, he may make the same study of his own home.

Locate the pipe that delivers water from the city mains to the building. Where is the valve that is provided to shut off the water from the building in case a pipe bursts or repairs are to be made to the plumbing? What other provisions are there for shutting off a portion of the water supply without cutting it off from the entire building? Trace the hot and cold water pipes in the basement.

Review Experiments 44, 45, and 52. Then study Figure 93 and explain how the water enters the water heater, is heated, and is

forced through the supply pipes when a faucet is opened.

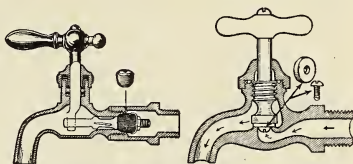
Obtain old faucets of different kinds if possible. Take them apart. Bring the parts to class and explain how to insert a new washer or Fuller ball to prevent faucets from leaking.

Voluntary Project 2.—To read the water meter.—Obtain a card of instructions from your local water or gas company, and learn how to read your water or your gas meter. If such cards of instruction are not issued in your city, send 15c to the Superintendent of Documents,

Washington, D. C., for a copy of Circular No. 55 of the Bureau of Standards, "Measurements for the Household."

Bring to class a diagram of the dials of your water meter or gas meter and tell what it registers.

The number on the outside of each circle indicates the number of cubic feet recorded for one complete revolution of the hand. Each circle has 10 divisions; each division thus indicates $\frac{1}{10}$ of the total for the circle. Thus the 10 circle records units; the 100 circle, tens; the 1000 circle, hundreds; etc. The reading is continuous. To ascertain the amount of water used in June, for example, you would have to subtract the reading taken on the 31st of May from the reading taken on the 30th of June.

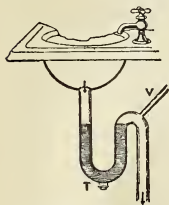


DIAGRAMS OF TWO TYPES OF FAUCETS

Above them are pictured the replaceable parts.

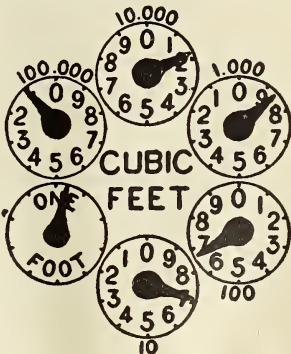
Commercially, one cubic foot is equal to 7 gallons.

Voluntary Project 3.—To study the action of soap.—Put a few drops of kerosene or other oil into a test tube half full of water. Since the oil is lighter than the water it rises to the surface.



WASTE-PIPE FROM A LAVATORY BOWL

Water always stands in the trap T to prevent the return of noxious gases from the sewer below. The vent V supplies air and prevents the trap from being siphoned out.



Courtesy of U. S. Bureau of Standards

DIAL OF WATER METER

1st hand shows $\frac{1}{10}$ of 100,000, or 10,000 cu. ft.
 2d hand shows $\frac{1}{10}$ of 10,000, or 1000 cu. ft.
 3d hand shows $\frac{1}{10}$ of 1000, or 100 cu. ft.
 4th hand shows $\frac{1}{10}$ of 100, or 10 cu. ft.
 5th hand shows $\frac{1}{10}$ of 10, or 1 cu. ft.

Shake the test tube vigorously. Does the oil mix with the water? Set the test tube aside and allow it to stand for a short time. Does the oil remain mixed with the water?

Put oil and water into another test tube and add finely shaved soap or a little soap solution. Shake the test tube vigorously and set it aside for a while. Does the oil now rise to the surface?

When the oil was shaken with the water, it divided into minute globules scattered through the water, giving the mixture a milky appearance. The oil soon separated from the water and floated on top of the water just as it did before the test tube was shaken. When soap was added and shaken with the oil and water, the globules remained in suspension and did not separate from the water when it was set aside for a while. A suspension of this kind is called an *emulsion*.

It is the power of emulsifying oil and grease that makes soap so useful as a cleansing agent. Water will not dissolve grease; but when soap solution is rubbed on oily or greasy materials, the oil or grease is converted into little droplets, each surrounded by a film of soap solution. These, with the little particles of dust and dirt which they contain, are easily removed by rinsing with water. The natural oils of the skin accumulate impurities from various sources. Since water will not dissolve this oil, soap is an essential in bathing.

Voluntary Project 4.—To study methods of softening hard water for domestic use.

Water that with the aid of carbon dioxide has dissolved limestone is *temporarily hard*. Temporarily hard water does not offer a serious problem in the household, as we have learned, because it may be softened by boiling.

Water that contains certain other mineral salts in solution (magnesium sulphate and calcium sulphate) is called *permanently hard* because it cannot be softened by boiling.

If soap is used in hard water, a sticky white substance is formed which will not dissolve in water.

When such water is used in bathing, the gummy compounds stick to the skin and prevent thorough cleansing. In laundering, the gummy substances get into the meshes of the cloth, stiffening and ruining it. It is wise, therefore, to remove these compounds from the water before attempting to use it for cleansing purposes.

For Laundry Use.—Washing soda is the most common softener for laundry purposes. The two mistakes commonly made in its use must be guarded against: do not make too strong a solution, and be sure that the soda is thoroughly dissolved. A failure to observe these cautions may result in injury to the clothes.

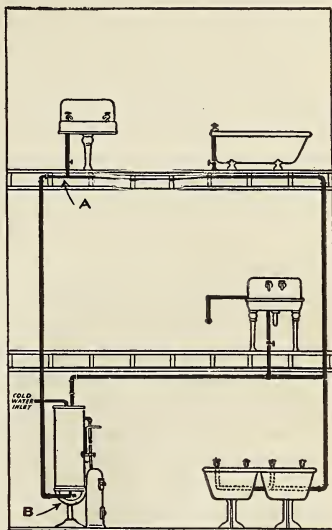
Dissolve 1 pound of washing soda in a quart of hot water. For most hard waters, 2 tablespoonfuls of this solution will soften a gallon of water.

If the water is unusually hard, draw it off first into tubs or barrels. Use more of the solution than is indicated in the directions above. Allow the water to stand until the curdy compounds have settled, and then draw water off the top of the containers for cleansing purposes.

For Delicate Fabrics.—Borax is much to be preferred to washing soda as a water softener because it will do no injury either to the hands or to delicate fabrics. It is so expensive, however, that it can not be used in great abundance. To soften water for washing delicate fabrics, dissolve 1 tablespoonful of borax in a cup of hot water. This will soften a gallon of water.

For Toilet Purposes.—(a) Borax used as suggested in the preceding paragraph will soften water satisfactorily for toilet uses.

(b) The addition of the juice of one or two lemons to a bowl of hard water softens it agreeably for washing or rinsing the hair.



HOT WATER SUPPLY IN A HOUSE

Trace the circulation. Sometimes the piping from A to B is omitted. In such a case, there is no circulation and the entire length of pipe must be emptied of cold water before hot water begins to flow.

III. FREEZING MIXTURES; ICE; COLD STORAGE

Freezing Mixtures.—Experiment 88. —Place some chopped ice in a beaker, and test the temperature. Add a generous amount of salt and test the temperature again. Has there been a fall of temperature?

Salt and some other substances tend to absorb water and to form a solution whenever it is possible. On a damp day salt sticks in the salt-shaker. This simply indicates that the salt has absorbed moisture from the atmosphere.

It is found that when salt or any other solid is in solution in water, more heat is required to boil the solution and a lower temperature to freeze it than are required by pure water. In ocean water, for example, there is so much dissolved material of different kinds that the density of the solution is sufficient to keep it from freezing until it reaches 28° F. , instead of 32° F. , the temperature at which fresh water freezes.

A *saturated* salt solution freezes only at -22° C. (-7° F.) although pure water freezes at 0° C. The freezing point of a salt solution may, therefore, be anywhere from slightly below 0° C. to -22° C. , dependent upon the strength of the solution. Salt placed directly upon ice will cause the ice to melt and form a solution if the temperature is above -22° C. This explains why salt may be used successfully to melt ice on porch steps, sidewalks, and car-track switches.

When ice is placed in salt water it takes from its surroundings the heat necessary to change it from the solid to the liquid state and continues to do this until the freezing point of the solution is reached. It thus happens that the temperature of such a solution may become much lower than the freezing point of water and yet the solution remain unfrozen. Most substances placed in such a solution become quickly frozen. A solution of this kind is used in freezing ice-cream. About three parts of snow or ice to one part of salt are the best proportions to use.

The Manufacture of Ice; Cold Storage.—We saw in Experiment 71 that when air was compressed it gave up heat and warmed its surroundings. When pressure was

removed, the air absorbed heat and cooled its surroundings. Other gases act in the same way. Water vapor, for example, may be compressed until it gives up so much heat that it returns to the liquid state.

Experiment 89.—(Teacher's Demonstration.)—*Before performing this experiment, be sure there is no flame in the room.* Put a drop of water on a large cork. Set a watch crystal on the drop of water. Fill the watch crystal with ether and allow it to evaporate. Blow gently over the surface of the ether with a blowpipe to hasten evaporation. If this experiment is carefully and speedily performed, the crystal will be frozen to the cork.

Experiment 60 with ether proved that when a liquid changes to a gas it takes up heat from its surroundings. Here the water lost so much of its heat to the evaporating ether that it changed to ice.

Ammonia is a gas that at ordinary temperatures is easily condensed by pressure into a liquid. (This liquid must not be confused with the aqua ammonia of our kitchens, which is simply water that has absorbed ammonia gas.) When the pressure is removed, the liquid ammonia quickly returns to the gaseous state, and in so doing it absorbs much heat.

Figure 94 shows the essential construction of an ice plant. The pump *A* compresses the ammonia gas into the pipes at *B*. The pressure condenses the gas into liquid, and the cold running water absorbs the heat given out in the process. The liquid thus cooled is allowed to run very slowly through the valve *C*, into the pipes at *D*. The valves in the pump *A* are so arranged that while the pump increases the pressure in the pipes at *B* it decreases the pressure in the pipes at *D*. Because of the low pressure in the pipes *D*, the liquid ammonia evaporates; that is, returns to the gaseous state. In so doing it absorbs heat very rapidly from its surroundings (page 171). The gaseous ammonia returns to *A* from the pipes

D because of the exhaust action of the pump. It is again compressed into the pipes at *B*. Thus the action continues without loss of ammonia.

The ammonia pipes pass through the brine into which cans of water have been lowered. Brine is used to surround the ice cans because it does not freeze unless its temperature is reduced many degrees below the temperature at which pure water freezes. The evaporation of the ammonia in the pipes reduces the temperature of the brine so low that the water in the cans is frozen, but the brine

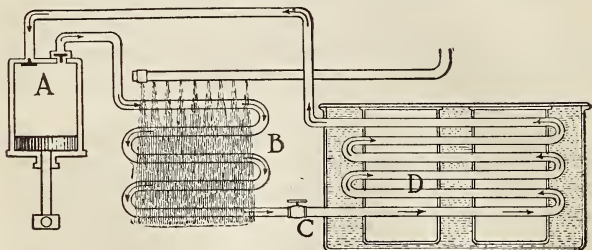


FIGURE 94

remains liquid, so that the cans may be easily removed.

In cold storage plants the pipes *D* are placed in the cold storage rooms to reduce the temperature of the air in the rooms, just as they reduce the temperature of the brine in the ice plant.

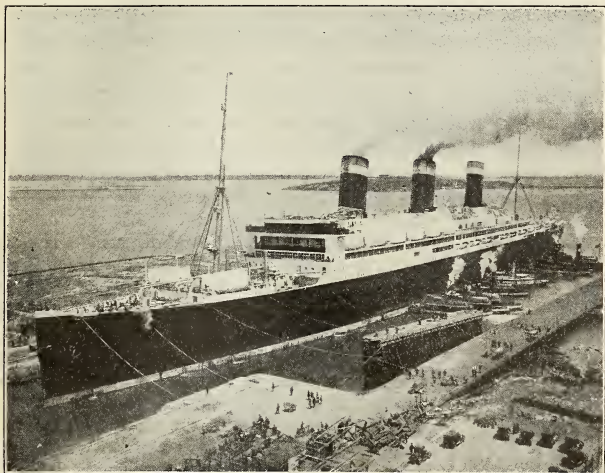
Written Report.—Make an investigation and write a short paper on what the manufacture of ice, transportation in refrigerator cars, and cold storage mean to your section of the country.

IV. WATER TRANSPORTATION AND WATER-POWER

Why Ships Float.—**Experiment 90.**—Prepare a block of wood having dimensions of $6 \times 4 \times 4$ cm. Bore a hole in one end of the block and fill it with sufficient lead so that it will readily sink in water. Tightly close the hole containing the lead and dip the block in melted

paraffin to make it entirely waterproof. Carefully measure the block and compute its volume in cubic centimeters.

Drive a small tack into the center of one of the smaller faces of the block. Attach a thread to the tack and lower the block into a cylinder graduated to cubic centimeters. Pour into the cylinder more than enough water to cover the block. Read on the cylinder scale the combined volume of the block and the water. Pull the block out of



AMERICA'S GREATEST PASSENGER SHIP

Edwin Levick Photo

The steamship *Leviathan* entering dry dock at Boston.

the water. Read on the scale the volume of the water left in the cylinder. Does the difference between the two readings equal the computed volume of the block?

From this experiment we learn that a body submerged in water displaces a volume of water equal to its own volume. A cubic block measuring exactly 96 cubic centimeters would displace 96 cubic centimeters of water.

Experiment 91.—Attach the block prepared for the previous experiment to a spring balance with a scale reading in grams, and weigh

it. Lower the block suspended from the scale by a thread into a vessel of water until it is entirely submerged. Does the block appear to weigh as much now as when out of water?

Compare the difference between the weight of the block in air and its apparent weight in water, with the weight of the water which the block displaced in the preceding experiment. One cubic centimeter of water weighs a gram.

From this experiment we learn that a body appears to lose weight when it is submerged in water and the amount of weight it loses is exactly equal to the weight of the volume of water it displaces. If a cubic centimeter of lead is weighed in water it will be found to weigh one gram less than in air. In other words the lead is pushed upward, or buoyed up, by a force exactly equal to the weight of a like volume of water.

Experiment 92.—If convenient, use an “overflow can.” If not, punch a hole near the top of a large tin can. (Drive the punch from the inside so that the flange will be on the outside.) Smear a little vaseline around the inside and the outside of the hole so that water will not cling to the tin. Place the can on a box on the table and fill with water until the water begins to run out of the hole. (Figure 95.) Accurately weigh a block similar to the block used in Experiment 90 but containing no lead. Weigh also a dry beaker. Place the beaker so that it will catch all the water overflowing from the hole in the tin can. Place the block in the can. As soon

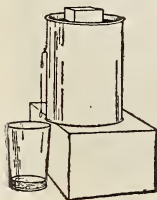


FIGURE 95

as water has ceased to run into the beaker, weigh the beaker with the water in it. Subtract the weight of the dry beaker from the weight of the beaker containing water, and you will have the weight of the water displaced by the block of wood. Compare this weight with the weight of the block.

Mark on the block the depth to which it sinks. About how much of the block was submerged?

A body floating in water displaces its own weight of water. Thus if a body is half as dense as water, it will sink half its volume; if one-third as dense, it will sink one-third

its volume. Representing the density of water by 1, what decimal fraction would represent the approximate density of the wood in the experiment? The density of any substance as compared with the density of water is known as the *specific density* of the substance. A solid piece of iron is much denser than water and when submerged displaces much less than its own weight of water. It therefore sinks. But an iron dish will float because its volume is so great that it displaces a weight of water equal to its own weight. If a hole is made in the dish and water is allowed to enter the hollow space, the dish begins to sink. The depth to which it sinks may be regulated by the amount of water admitted.

How a Submarine Operates.—Experiment 93.—Obtain a quart milk bottle and fill it two-thirds full of water. Put enough water into a pill phial so that when it is *inverted* in water it will float with the bottom of the phial *barely* at the surface. Float this in the water of the milk bottle. Cover the mouth of the milk bottle with a piece of sheet rubber such as dentists use for dams, and bind the rubber air-tight about the neck of the bottle with thread or strong rubber bands. (Figure 96.)

Press down on the rubber covering. Does the phial sink? Release the pressure. Does the phial rise?

When you pressed on the rubber covering of the milk bottle, you compressed the air above the water. This increased the pressure on the surface of the water and this pressure being conveyed in all directions through the water forced more water into the phial. This in turn compressed the air in the phial. When you released the pressure, the compressed air in the phial returned to its original volume and forced the extra water out of the phial. Thus the phial rose. This illustrates the principle of the submarine.

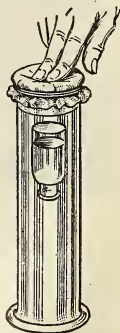
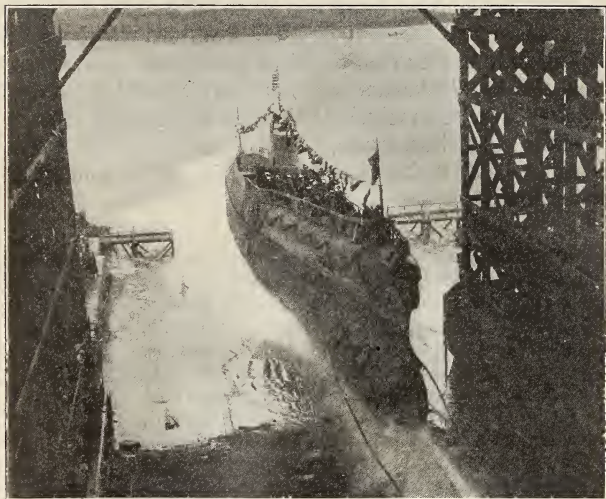


FIGURE 96

Submarines are boats so constructed as to be water-tight even when submerged. Special compartments are provided to which water can be admitted and from which it can be driven out. When the commander of a submarine wishes to submerge his vessel, he gives the order to admit



Wide World Photo

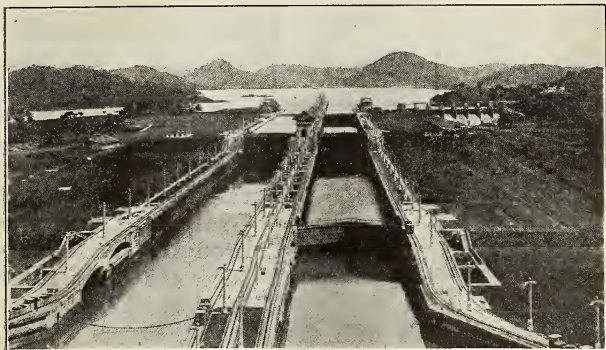
ONE OF THE LARGEST SUBMARINES IN THE WORLD

This is the V-7, first of a fleet of nine such vessels, shown as it was being launched in 1924 at the Portsmouth (N. H.) Navy Yard.

water to the compartments. When the submarine reaches a weight within about a hundred pounds of that of an equal volume of water, it is ready to dive. Now as the submarine moves along near the surface, the horizontal diving rudders are slanted downward, thus pulling the boat downward and keeping it submerged so long as it moves forward. To make the submarine rise, the operators force water out of the tanks by means of compressed air until

the submarine is much lighter than an equal volume of water. When under water the boat operates by means of electric storage batteries.

The Improvement of Waterways.—Two thousand years before Christ the Babylonians connected the Tigris and Euphrates, thus showing that they realized the commercial advantages of improved waterways. More than two



Wide World Photo

MIRAFLORES LOCKS, PANAMA CANAL

The gates in the right chamber are closed. A mile across the lake are the Pedro Miguel locks.

thousand four hundred years ago China began the extending of her waterways by building a canal six hundred miles long. Since then almost every civilized nation has discovered for itself the need of increasing the usefulness of its natural waterways and has built artificial channels in order to extend cheap and easy facilities for transportation.

Many European countries are veritable networks of improved river channels and canals. The Seine carries the greater part of the ocean freight to and from Paris. The Rhine is used to the very limit of its navigable course.

More than ninety-five per cent of the Thames is open to navigation. A canal thirty-five miles long and twenty-eight feet deep conducts ocean-going vessels to and from Manchester. England alone has over two thousand miles of canals.

America has been slower to awake to the importance of this work than have the nations of western Europe with their denser populations.

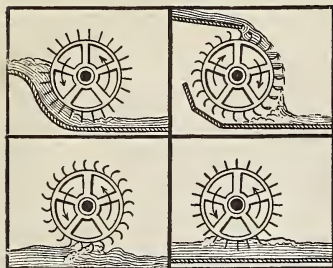


FIGURE 97.—DIAGRAMS OF OLD-FASHIONED WATER WHEELS

It is to be hoped that the Erie Canal, connecting the Hudson River and the Great Lakes, will some time be made deep enough for ocean-going vessels. By extending the Chicago Drainage Canal and dredging the Illinois River the Great Lakes could be connected by

navigable channels with the great Mississippi system. The dredging of portions of the Mississippi channel, the straightening of its course, and the building of additional permanent levees must some day be accomplished. Such improvements would render many cities along its banks veritable inland seaports.

At first canals were built entirely for inland carriage, but later canals of international importance have been constructed to shorten the routes of ocean-going steamers. The Suez Canal reduced the distance by boat from England to India by about one-third. The Kiel Canal, which connects the Baltic with the North Sea, has been of tremendous commercial and naval importance to Germany. The Panama Canal is a monument to American efficiency. It gives easy water transportation from the manufacturing

cities in the eastern and the central part of the United States to the Orient and to the western coasts of North and South America. It also allows the easy concentration of the United States Navy on either the eastern or the western coast.

Water-power.—Any one who has ever tried to row against the current of a stream knows something of the power of running water. The power of the waters that flow over Niagara can hardly be imagined. Waterfalls furnish natural power sites. Where the flow of water is gradual, it is possible to dam up the water so that an artificial fall is created. It is in this way that the Mississippi at Keokuk is made to furnish tremendous power.

Old-fashioned mill-wheels used the power of water in a very inefficient way. (Figure 97.) Not more than twenty-five per cent of the power of the water was utilized. About a century ago a much more efficient wheel known as the water turbine was invented, but it was not greatly used until the electric dynamo was invented for generating electric power. The water turbine is somewhat like the wheel of a windmill in appearance. (Figure 98.) It is enclosed in a pipe through which the water passes. Thus almost the entire force of the falling water is directed to the turning of the wheel. The turbine is connected with a dynamo in the power house above, which generates electricity that is often conveyed for use hundreds of miles from the power site.

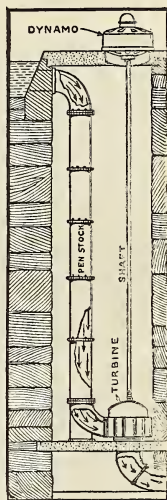
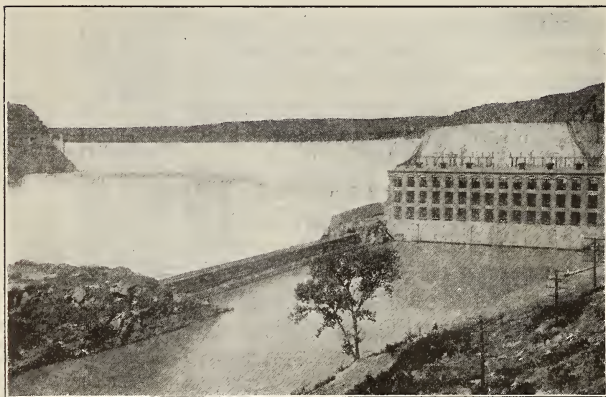


FIGURE 98.—DIAGRAM OF A WATER TURBINE

Prominent engineers have proposed that steps be taken

to divide the country into districts. It is suggested that the water-power of each district be thoroughly developed and the resulting electric power be distributed to all parts of the district.

Conservation of Water-power.—When combustion is used as a source of energy, man is drawing upon his bank



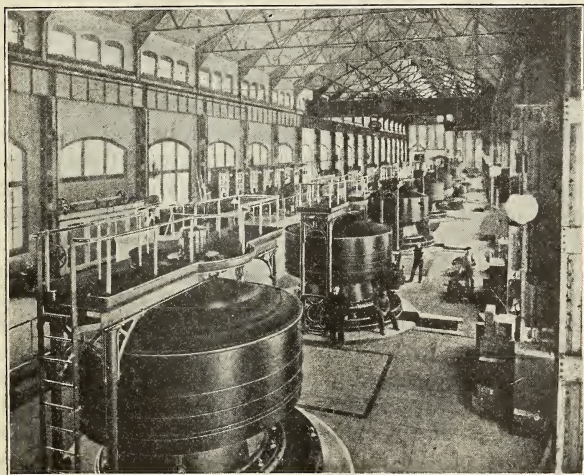
Courtesy of Chicago, Milwaukee and St. Paul Railway

POWER PLANT AND DAM OF THE MONTANA POWER COMPANY

This plant at Great Falls, Montana, transforms energy of running water into electrical energy by which trains are operated over 641 miles of track.

account with nature, and is using up the stored energy of the earth. But in utilizing the energy of blowing wind and running water, he is conserving energy that would otherwise be wasted. "The mill can never grind again with water that is past." There is, however, only so much water-power in the country and it is exceedingly important that these sources of power should remain in the possession of all the people as represented by their Government and not be monopolized for the commercial gain of

a few people. In recent years the United States Government has arranged to retain control of power sites on public land, and to lease rather than sell water-power to individuals and corporations. Running water is a never-



ELECTRIC POWER PLANT AT NIAGARA

Conserving the energy of running water by transforming it into usable electrical energy. These dynamos are run by water turbines.

stopping, sun-power engine, and its use should be the birthright of mankind.

SUMMARY

Primitive man was dependent upon streams and flowing springs for his water supply. In many backward countries water is peddled from door to door. Rural communities that are dependent on shallow wells for their water supply should take great care to keep it pure.

The supplying of water to populous communities has

always been one of man's great problems. Aqueducts brought water from the mountains to the ancient cities. Later great cities depended upon underground sources. To-day most of the great cities of the world are largely, if not wholly, dependent upon near-by rivers and lakes for the water they use. The larger coast and mountain cities have been turning one by one to the hills and mountains for their pure water supplies.

The second great problem of large cities is to keep the water supply pure. All cities with upland reservoirs keep them constantly guarded against pollution. Cities that obtain water from lakes or rivers are put to the expense of establishing complex clarifying and purifying plants.

Ancient cities were dependent upon gravity to bring water to them from sources higher than the community served. Whenever possible, modern cities obtain their water supplies by the same method, but we now have the advantages of pressure pumps. Gravity combined with the work of pressure pumps makes it possible for water to be delivered not only to all parts of a city but to the top floors of the tallest buildings. Modern plumbing makes it possible for water to be delivered to any portion of a house and provides sanitary conditions unknown until a few decades ago.

A saturated salt solution freezes at only -22° C. The manufacture of ice and cold storage are dependent primarily on the principle that when pressure is removed from a gas, it absorbs heat and cools its surroundings. Ammonia is a gas that at ordinary temperature is easily compressed into a liquid. When the pressure is removed, the liquid ammonia returns to the gaseous state and in so doing it absorbs much heat. An ice-making machine is so arranged that the heat is taken from the water that is to be frozen.

A ship floats because it weighs the same as the weight of the water it displaces. The submarine is so constructed that it may vary its weight by admitting water or driving out water from special compartments. When all the water is driven out of the compartments constructed for that purpose, the submarine may float on the surface of the water. The submarine may submerge itself by admitting water to its tanks.

Every civilized nation has discovered for itself the need of increasing the usefulness of its natural waterways and of building artificial water channels for transportation. Many European countries are veritable networks of natural and artificial waterways. America has been slower to awaken to the importance of this work, but many large projects are now contemplated by her. Up to the present time, the Panama Canal is the greatest artificial waterway to the credit of the United States.

Old-fashioned mill-wheels used the power of running water in a very inefficient way. The modern water turbine utilizes almost the entire force of falling water. The United States is beginning to learn the necessity of making use of the energy of running water. It is probable that within the next fifty years, a very large percentage of the work in this country will be done by the energy of flowing water. This will result in a tremendous conservation of fuel.

QUESTIONS

What are some of the primitive methods of supplying water?

In what ways must care be exercised by people in rural communities to prevent contamination of their wells?

How were Rome and Carthage and other ancient cities supplied with water?

Mention some cities that obtain their water supplies from great lakes.

Mention some cities that are dependent upon rivers for their water supplies.

Mention some cities that have gone to the uplands for their water supplies.

How do cities along the Great Lakes avoid contamination of their water supplies?

What means are used by cities like St. Louis for the purification of river water?

How is water that comes from higher levels delivered through cities?

When cities obtain water from low levels, what means must they use for delivery to the consumer?

Explain the action of soap as a cleansing agent.

Explain two methods of softening hard water for domestic use.

Why is salt used in freezing ice cream?

What is the main principle underlying cold storage and the manufacture of ice?

Why does a ship made of materials that are heavier than water float?

By what means does a submarine submerge or rise to the surface?

What are some of the most important plans for extending inland waterways in the United States?

What is a water turbine?

Why should the source of water-power be controlled by the government?

What advantages are there in the use of water-power?

CHAPTER XI

WEATHER AND CLIMATE

*Nothing that is can pause or stay;
The moon will wax, the moon will wane,
The mist and cloud will turn to rain,
The rain to mist and cloud again.*—Longfellow.

We shall find that a study of weather and climate involves much that we have learned about heat, air, and water. If we add to these things some of the effects of the rotation of the earth on its axis and of its revolution about the sun, we have most of the elements necessary for a study of changing conditions that make up what we call weather and climate.

The Atmosphere Is Both Sun-shield and Blanket.—We have found that the sun transmits both heat and light to the surface of the earth. Although the earth receives but a very tiny fraction of the sun's heat, that heat would be sufficient to destroy every living thing between sunrise and sunset if it were not for the protection of our atmosphere.

The atmosphere which envelopes the earth serves both as a sun-shield and a blanket. It has been estimated that if there were no atmosphere, the mean temperature of the earth's surface during the day would be 350° F., and during the night —123° F. On the moon, where there is no atmosphere, there can be no life as we know it.

To understand how the atmosphere performs such vital services, we shall have to review a few facts concerning it. As we have already learned, three-fourths of the earth's

atmosphere is compressed into the layers below the top of the highest mountain. About half of the volume of the atmosphere is compressed into layers extending only about $3\frac{1}{2}$ miles above the earth's surface. These lower layers contain a great deal of moisture and dust. It is chiefly this dust and moisture that make the atmosphere so efficient as both blanket and sun-shield.

If there were no moisture nor dust in the atmosphere, the atmosphere would be perfectly clear at all times, and the heat of the sun would be radiated through this transparent envelope (page 125) to be absorbed by all exposed surfaces. At sunset, the earth would begin rapidly to radiate its heat back through the transparent atmosphere into outer space. Thus the days would be withering and the nights frigid. But the little particles of dust and moisture which float in the lower layers of atmosphere absorb about half of the radiant heat of the sun as it travels toward the earth. What heat gets through to the earth's surface is there absorbed or reflected back toward outer space. When the heat received from the sun by the land and water surfaces is radiated or reflected back toward outer space, most of it is caught and held by the moisture and dust of the air. But we must not give all the credit for service to the dust and moisture. The atmosphere is necessary as a sea of gas for the dust and moisture to float in.

If we go up a mountain, we find that the amount of water vapor increases for the first two thousand feet. Then it begins to decrease. Above the height of seven miles, the atmosphere contains almost no dust or moisture, and so it absorbs very little of the sun's radiation. The amount of sun radiation that strikes the surface of a high mountain is about the same as that which falls upon an equal surface in the valley. Visitors coming from the lowlands to mountain country notice how much hotter the

sun's rays seem to be than in the valleys. This is because the clearer atmosphere allows more of the sun's radiant energy to reach the upland surfaces. But the thin clear atmosphere does not "blanket in" the heat. High mountain tops are, therefore, cold and often covered with snow.

Why is it that early frosts are likely to come on clear nights rather than on cloudy ones? Explain why smoky fires are built around cranberry bogs, and orchards are smudged,



Courtesy U. S. Weather Bureau

SMUDGING TO PREVENT DAMAGE BY FROST AT MEDFORD, OREGON

on nights when there is likely to be frost. What is the advantage of locating an astronomical observatory on a mountain? Review pages 126 and 127 and then tell which absorbs more of the radiant energy of the sun, land or water surface. Which reflects more of the radiant heat of the sun, a land or a water surface?

I. THE CHANGING DAYS AND SEASONS

Inclination of the Earth's Axis.—Experiment 94.—(A) In a darkened room place a globe a short distance from a small but strong light. Rotate the globe with its axis at right angles to the line which joins the centers of the globe and light. (Figure 99, A.) How much of the globe is illuminated by the light? Is the same part of the globe illuminated all the time? Does any place receive light for a longer time during a rotation than any other place? Remove the globe to the opposite side of the light without changing the direction of its axis. When rotated, is there any change in the globe's illumination?

(B) Now make the axis on which the globe rotates parallel to the line joining the centers of the globe and light. (Figure 99, B.) Rotate the globe. How much of the globe is illuminated by the light? Is the same part illuminated all the time? Does any place receive light for a longer time during a rotation than any other place on the

globe? Remove the globe to the opposite side of the light without changing the direction of its axis. When the globe is rotated, is there any change in its illumination? If so, what?

(C) Place the globe so that its axis is inclined about 25 degrees from the perpendicular to the line joining the centers of the globe and light. (Figure 99, C.) Rotate the globe. How much of it is illuminated? Is the same part illuminated all the time? Do any places in the illuminated part receive light for a longer time during a rotation than other places? Remove the globe to the opposite side of the light without changing the direction of its axis. When the globe is rotated, is there any change in the length of time of illumination of the places before noted? If so, what?

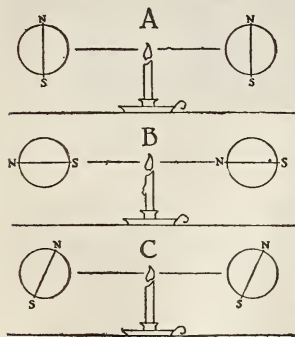


FIGURE 99.—RELATIVE POSITIONS OF GLOBE AND LIGHT

Corresponding to A, B, and C of Experiment 94.

As was seen in the previous experiment, the direction of the axis of a rotating globe has much to do with the light which different parts of it will receive from a luminous object.

When the axis of the revolving globe was at right angles to the line joining the globe and the light, no place on the surface of the globe received light for a longer time than any other place.

This was not true when the axis was at any other angle.

Days and Nights of Varying Length.—The axis of the earth is inclined $23\frac{1}{2}^{\circ}$ from the perpendicular to a line drawn from the center of the earth to the center of the sun. The third part (C) of Experiment 94, therefore, best illustrates the relative positions of the earth and the sun. Thus our days and nights vary in length during the year, because in summer the northern hemisphere is inclined toward the sun and in winter away from it

Daylight Saving.—In midsummer the sun rises between four and five o'clock in middle latitudes. Thus it is well up in the heavens before the average city-dweller is astir. Some cities, therefore, provide that beginning in April or in May the clock shall be set ahead one hour. Thus seven o'clock in the morning becomes eight o'clock, and the beginning of the day's work is brought an hour nearer to sunrise. This arrangement allows an hour more of sunlight for recreation or home duties at the close of the working day.

During the war, the United States Congress passed a "daylight saving" law, chiefly to effect a saving of fuel for artificial lighting. But the majority of the people of the United States, who are dwellers on farms or in small towns, were in the habit of saving daylight by getting up early and going to bed early. They found it inconvenient to have their working schedules changed, and so the law was repealed.

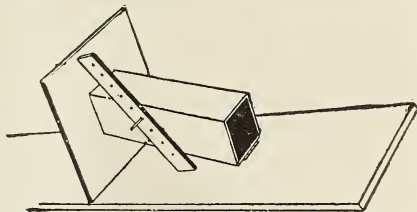


FIGURE 100.—APPARATUS FOR SHOWING THE HEATING EFFECTS OF SUN'S RAYS

The Causes of the Seasons.—**Experiment 95.**—Cut a hole 4 in. square in the center of a board 12 in. square. Fit tightly into this hole one end of a wooden tube 4 in. square and 1 ft. long. Paint the inside and outside of the tube a dull black. Hinge the opposite end of this tube 10 in. from the end of a baseboard 2 ft. long and 16 in. wide, having 6 in. of the board on either side of the tube. (Figure 100.)

On a clear day place this apparatus out of doors on a table freely exposed to the sun, with a piece of paper on the baseboard under the end of the tube. Point the tube directly at the sun in the early morning, in the middle of the forenoon, at noon, in the middle of the afternoon and about sunset. Mark on the paper the amount of surface

illuminated by the sunlight passing through the tube at each of these different times. Why are different amounts of surface covered at these different times?

Place a thermometer in the centers of the surfaces covered by the sunlight passing through the tube at these different times. Note the different readings of the thermometer. Can you suggest a reason why they are not alike? The opening exposed to the rays has been the same throughout the experiment.

The number of rays of the sun which fall upon a given area depends upon the angle at which they strike the sur-

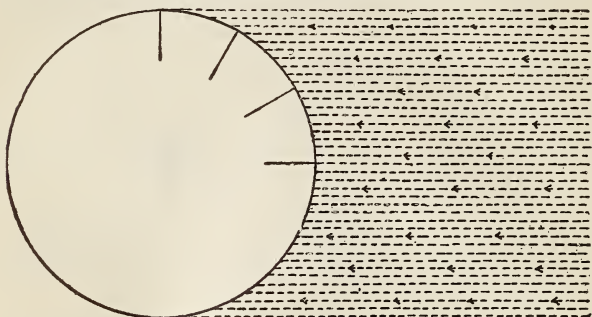


FIGURE 101.—HEATING EFFECTS OF SUN'S RAYS

Heating effects depend upon the angle at which the sun's rays strike the earth's surface.

face. Figure 101 shows that the same number of rays fall upon a much smaller surface when the direction of the sun is vertical than when it is nearly horizontal. In the 30-degree arcs there are $2\frac{1}{2}$, 7, and $9\frac{1}{2}$ ray spaces respectively. The sun is here considered to be vertical at the equator, as it is on March 21 and September 22. Thus on these days, other conditions being the same, about one-fourth as much heat from the sun falls upon the 30° about the pole as upon the 30° north of the equator.

The more nearly vertical the rays, the greater the number that fall upon a given area, and the greater the amount

of heat received by that area. In January we are closest to the sun, but its rays strike our hemisphere more aslant and therefore fewer heat rays fall upon a given area than in July.

From March to September, the days are longer and the nights shorter throughout all the northern hemisphere. More heat is, therefore, received in the northern hemisphere during these six months, not only because the rays of the sun fall more nearly vertical but also because the length of the day is increased.

The amount of heat received from the sun continues to increase as long as the sun appears to move north. The rays of the sun strike vertically the farthest point north on the 22nd of June. This is called the *summer solstice*. At this time our days are the longest and our nights are the shortest. But the days are not the hottest, as the heat gradually accumulates for some time, more being received each day than is given off. On the 22nd of June all points within $23\frac{1}{2}^{\circ}$ of the north pole, as at North Cape, have twenty-four hours of sunshine; and the amount of heat received at the pole during these twenty-four hours is greater than that received at the equator, where the day is only about half as long. But so much of the heat is absorbed by the melting of ice and the heating of the seas that have grown frigid during the six months of night that the sun's heating effect on the atmosphere is relatively small.

As the earth proceeds in its orbit from this point, the



PICTURE TAKEN AT MIDNIGHT ON NORTH
CAPE

The sun had not set even at midnight.

inclination of the north pole toward the sun becomes less and less, until on the 22nd of September the sun is directly over the equator. (Figure 102.) The north pole now begins to point away from the sun. On December 22, the direct rays of the sun fall upon the farthest point south, our days being then the shortest and the days in the

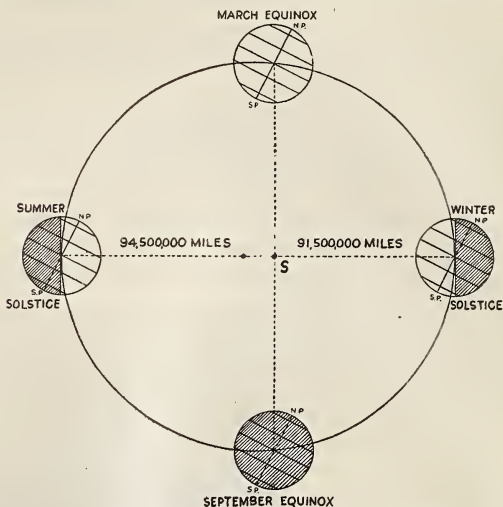


FIGURE 102.—THE EARTH'S REVOLUTION IN ITS ORBIT

Diagram showing relative positions of the earth and sun on June 22, September 22, December 22, and March 21.

southern hemisphere the longest. From this point until March 21, when the sun is again vertical over the equator, the inclination of the north pole away from the sun decreases. The days when the sun is over the equator are called the *autumnal* (Sept. 22) and *vernal* (March 21) *equinoxes*, since the days and nights are then of equal length all over the earth.

Since the change in the length of the day and in the direction of the sun's rays is very small within the tropics, the change in the amount of heat received is very slight, so that in this region there is almost no change of seasons. But at the poles, where for six months there is continuous night and for six months continuous day, the change of seasons is exceedingly great. At middle latitudes the changes, though marked, are not excessive.

There are then two causes which combine to give us our changes of seasons: the revolution of the earth around the sun, and the inclination of the earth's axis to the plane of its orbit.

II. WIND BELTS OF THE EARTH

Circulation of Air.—The atmosphere is the circulatory medium of the earth, as blood is for the animal and sap for the plant. Without it the activities of the earth would stagnate. It scatters the seeds of plant life over the face of the earth. It carries water evaporated from the sea to the land, replenishes the underground reservoirs for man's use, and transports reserve supplies to the mountains for the use of cities, for power, and for irrigation. It cools the hot regions with the invigorating breath from the mountains and from the uniformly tempered sea. It warms the cold places by bearing to them the heat taken from the warmer ocean waters and from the parched places of the earth. By its movements, it keeps the very fires of man's factories and engines burning, sweeps the smoke and foul air away from his cities, and bears his commerce across the sea.

Experiment 96.—On a day when the temperature in the room is considerably higher than that outside, open a window at the top and bottom and hold a strip of tissue paper in front of each opening. Is there an air current, and if so, in what direction does it move at the top and at the bottom of the window? What causes "drafts" in a room?

If a column of air is heated it becomes lighter (page 123) and the atmospheric pressure at that point is lessened. Cooler air being heavier flows in below and forces the heated air to rise. Thus with the unequal heating of different places on the earth's surface, there is a constant tendency of air to move from places of high pressure to places of low pressure; and so the air is constantly in motion, tending to transfer its heat and to equalize the atmospheric pressure.

Such a transfer of air, along the surface, from the place where the pressure is greater to that where it is less great, we call *wind*. Winds are named from the direction from which they come. A west wind is a wind that blows *from* the west.

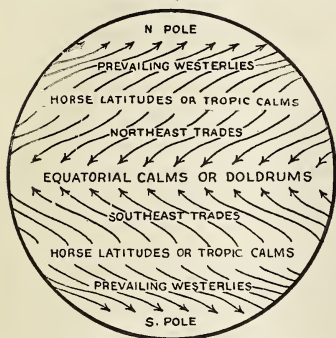
The strength of the wind depends upon the difference in air pressures. If a very hot column of air comes in contact with a very cool column of air, the heavy cool air will rush in under the light warm air and force it upward with tremendous rapidity. The greater the difference in temperature between two adjoining areas, the greater is the difference in pressures, and the greater is the speed of the wind from the cold area to the warm area.

The Doldrums.—Some part of the torrid zone is always receiving the vertical rays of the sun. Owing to the inclination of the earth's axis and to the annual revolution of the earth about the sun, the line that receives the direct radiation of the sun shifts all the way from $23\frac{1}{2}^{\circ}$ north of the equator to $23\frac{1}{2}^{\circ}$ south. Thus the belt of greatest heat of the earth, the *heat equator*, shifts somewhat to the north of the earth's equator during our summer, and moves slightly southward during our winter.

The air over any warm body of land or water receives heat from the surfaces it comes in contact with, and the heated air rises. As the air at the heat equator receives a

large amount of heat both by direct radiation from the sun and by reflection and radiation from the land and water surfaces, it becomes warm and light and is forced into a constant up-draft by cooler air flowing in. Here, then, near the heat equator is a belt of calms and light breezes called the *doldrums*. In this belt of constantly ascending air, sailing ships have been becalmed for days and even weeks.

Since the air here is being forced up and is losing heat, thus losing capacity to hold moisture (page 166), this is a cloudy, rainy belt of high temperature in which much of the land is marshy and the vegetation so rank and luxuriant that agriculture is exceedingly difficult.



WIND BELTS OF THE EARTH

about 28° of latitude are belts in which constant winds blow toward the doldrum belt and supply the air for the upward current there. In the northern hemisphere these winds have a northeast to southwest direction and in the southern hemisphere a southeast to northwest direction. They are the most constant winds on the globe in their intensity and direction, and are called *trade winds*. The trade wind belts move north and south, of course, as the heat equator shifts with the sun's apparent movements.

Trade Winds.—Extending north and south of the doldrums to

The Effect of the Earth's Rotation on North and South Winds.—Experiment 97.—Fix a rotating globe on the surface of a

table with its axis perpendicular to the table-top. Rotate the globe from left to right and while it is revolving draw a piece of chalk from the pole toward the equator. Does the line as marked on the globe follow a meridian? What is its general direction in lower latitudes? While the globe is revolving, allow a drop of water to run from one pole to the other. Note the path it takes.

Why the trade winds coming toward the equator take on a westerly direction is illustrated by the course taken by the drop of water.

As the earth is about 25,000 miles in circumference and turns on its axis once in 24 hours, a body situated at the equator is carried from west to east at the rate of about 1000 miles per hour, whereas a body at the poles simply turns around during a rotation.

Thus a body at any point north or south of the equator is being carried around by the rotating earth with less speed than a body on the line of the equator.

Let us follow the trade winds as they start from either hemisphere toward the equator. They are going from slower moving latitudes toward the fastest moving belt. As the winds blow through the faster moving latitudes, they fail to take on the speed of these faster moving belts. Thus they lag behind and appear to move in a direction opposite to the rotation of the earth. For that reason, as the earth turns from west to east, the trade winds appear to have an east to west motion; just as to a person riding east in a rapidly moving open car on a calm day there seems to be a strong west "breeze." (That the "breeze" is produced by the motion of the car and not by movements of the atmosphere is shown when the car comes to a standstill.)

Thus the lagging of the slower trade winds coming into faster moving belts gives them a trend toward the west. And so trade winds from the north blow toward the south-

west, while trade winds from south of the equator blow toward the northwest.

On the other hand, suppose an air current is moving from the direction of the equator toward either pole. It has greater velocity toward the east than the part of the earth's surface it is approaching, and so instead of blowing due north or south, it takes a northeast or southeast course. It can be seen, then, that all air currents moving toward the equator lag toward the west, and all air currents blowing toward either pole outstrip the slower moving surfaces over which they blow and so have an eastward direction.

Horse Latitudes.—Now it becomes necessary to trace some air currents in the upper air. The air which rises in the doldrums is cooled as it ascends. It thus loses most of its moisture. Why? When these upward currents reach a considerable height, the cooled air spreads out and flows "downhill," both northward and southward toward the poles. These upper currents of cooled air take on an eastward trend, as has been shown, and so flow above the trade winds and in exactly opposite directions to them. For this reason, these upper currents are called *anti-trade winds*.

When these upper currents reach the latitudes of 30° to 35° on each side of the equator, the heavy dry air begins to sink to the surface of the earth. Since the air is here descending the surface movements are light and irregular. These, like the doldrums, are regions of calms. But unlike the doldrums, they are dry belts; since the descending air is increasing in temperature, owing to adiabatic heating (page 192), and thus its power to hold moisture is increasing. Therefore the tendency of the atmosphere in these belts is to take up moisture rather than to deposit it.

These belts of calms on the poleward sides of the trade

winds are called the *horse latitudes*, or *belts of tropical calms*. They received this name in colonial times. Sailing vessels carrying horses from New England to the West Indies were often becalmed so long in these latitudes that their water supply ran low. Frequently it became necessary to throw many of the horses overboard, and sometimes the entire cargo had to be sacrificed. These belts move north and south, as do the doldrums and trade winds, with the apparent north and south shifting of the sun. In this way, they bring the dry seasons to the lands which they visit as they move northward and southward with the seasons.

The Prevailing Westerlies.—Assignment.—Some day when wisps of clouds are floating very high, sight one of them by means of some stationary object and see in what direction it is traveling.

Only a part of the air of the anti-trade winds sinks to the earth's surface in the horse latitudes. A great deal of it continues to move farther toward the poles. We have seen that this stream of upper air has an eastward trend. The direction taken by the wisps of clouds shows that the eastward trend is so marked that the northward drift is almost unnoticeable. This stream of eastward bound air currents is far above the influence of surface conditions and nothing disturbs the steadiness of its eastward flow.

This broad belt, where the upper air currents move steadily out of the west toward the east, extends over most of the two temperate and frigid zones. It is known as the belt of the *prevailing westerlies*. In it are situated all the great nations of the earth, because as a whole the climate of this belt is most favorable to man.

III. WIND AND WEATHER

Relation of the Prevailing Westerlies to Our Weather.
—The changes of weather which we know and constantly

talk about in the region of prevailing westerlies are only remotely connected with the grander movements of the atmosphere we have been discussing. The prevailing westerlies, for example, follow their steady course from two to three miles overhead. Between these upper currents and the surface of the earth is what we may call an under tow of the atmosphere, two or three miles deep. It is the movements of air in this under tow that give us our wind and weather.

The movements of air in these lower layers of atmosphere are greatly influenced by the varying conditions of the earth's surface. All these movements, whether they bring us fair or stormy weather, take the form of gigantic whirls. There is one very important relation between the steady eastbound stream of the prevailing westerlies high above us and the whirls in our under tow. The overlying stream lends its eastward motion to the under tow and drives the whirls of weather in continuous procession across the country from west to east.

Charting Weather Conditions.—Expensive weather bureaus are maintained not only by the United States, but by all the other highly civilized countries of the world. Records are kept also by sea captains and by other observers throughout the world, and these are gathered together by scientific men and from them are made charts of the weather conditions over the entire surface of the earth. Every year more and more data are being collected and these charts are becoming more and more reliable.

These charts are of great value, since they aid in the explanation of climatic conditions in different parts of the world. The results of the data thus gathered together have been of untold service to commerce and each year have saved many lives and a vast amount of wealth.

How Weather Maps Are Made.—In charting weather conditions for the United States, it is essential that the varying temperatures, the readings of the barometer, and the directions of the surface winds should be known, and a record of them made and preserved. In the case of the

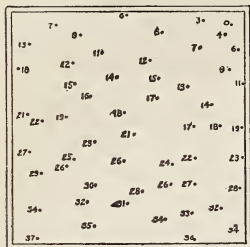


FIGURE 103

temperature readings, for example, this might be done by taking a map and writing their temperatures above the different places marked on the map. This would make a map full of small figures and very difficult to read.

A much better method has been developed and is now almost universally used. In making this map the temperatures

are first written on the map and then lines are drawn through places which have the same temperature. These lines are called *isotherms* and the map is called an *isothermal map*. By the use of such a map it is possible at a glance to determine the temperature prevailing at any place and to see the relation which this has to the temperature of other places on the map. As a rule the isotherms are not drawn for each degree, but only for each ten degrees.

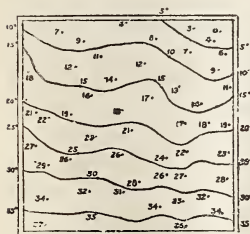


FIGURE 104

When the map has been constructed, copies are made in which the figures are left off and only the isotherms are preserved. In Figure 103 we have a plan before the isotherms are drawn, and in Figure 104 after the isotherms are drawn. Figure 105 is a typical isothermal diagram. If the map itself were sketched, it would be an isothermal map.

Maps recording barometric conditions are made in the same way as the isothermal maps, only their lines pass through places of equal barometric pressure instead of places of equal temperature. These lines are called *isobars*.

Weather maps are prepared by the United States Weather Bureau every day, on which are both the isotherms and isobars for that day. The data for these maps are telegraphed each morning from stations scattered all over the settled part of North America.

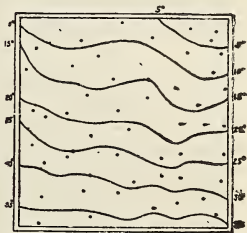


FIGURE 105

Reading the Weather Map.—

Assignment.—Obtain a weather map. Trace the isobars and isotherms. Notice the areas marked “High” and “Low.” What general shape do the isobars or lines of equal barometric pressure take about the centers of these high and low areas?

Notice how much lower the readings of the barometer are at the center of an area marked “Low” than at the center of an area marked “High.” What does this indicate? (See page 183.) Note how extensive these Low and High areas are. The Low area on the map opposite this page, is unusually extensive.

A report from all the weather stations of the United States at any one time shows many different readings of the barometer. Part of these differences is owing to altitude, but after allowance is made for varying altitudes, the barometer readings are still different. When these readings are arranged on a map by means of isobars to show their relations, areas of high pressure and areas of low pressure are shown. The centers of these areas are marked “High” and “Low” respectively on the weather map. These are the gigantic whirls that bring us our changes of weather.

Naturally the air from areas of high pressure is moving

toward areas of low pressure. Thus the air in our great under tow is always moving in its unsuccessful effort to equalize the pressure. A Low is called a *cyclone*, and a High is called an *anti-cyclone*. These areas may vary from 500 to 1,000 or more miles in diameter. There is a constant procession of cyclones, followed by anti-cyclones, moving across the country from west to east under the drive of the prevailing westerlies.

A Cyclone Is a Storm Area.—Assignment.—Draw water into a lavatory bowl, a sink, or a bath-tub to the depth of a few inches. Be sure that the waste pipe is perfectly clear so that the water may run out rapidly. Open the waste pipe and allow the water to run out. As it runs out, does it seem to run down directly from above or to circle about the center of the waste pipe as it leaves the bowl?

An area of low pressure is an accumulation of air that has become warmer than the surrounding air. This warm air is lighter, hence the lower pressure of a cyclone area. The center of the area of low pressure is warmest of all,



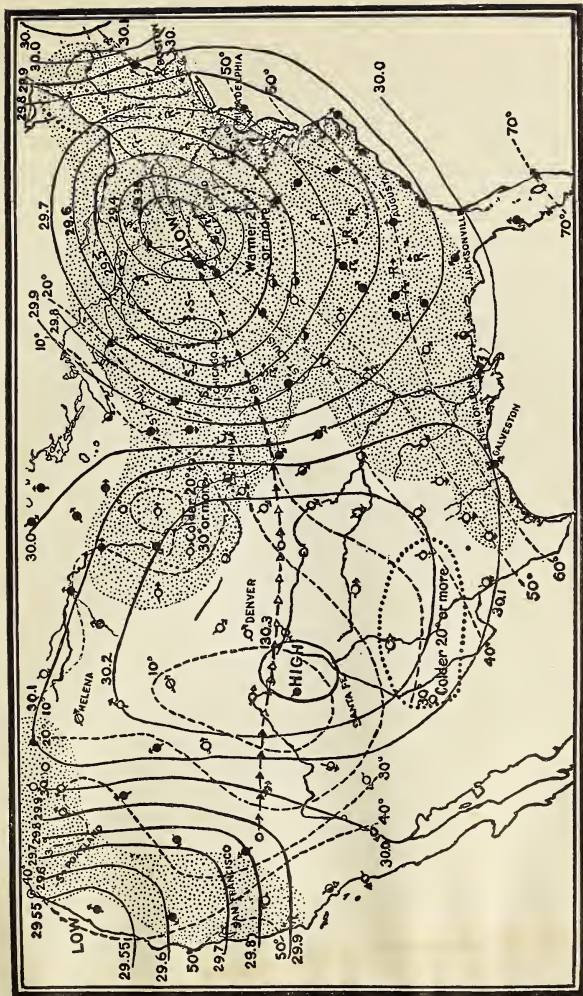
FIGURE 106.—DIRECTIONS OF WINDS IN AN ANTI-CYCLONE AND IN A CYCLONE

and the warm air is continually being forced up there. As this warm air rises, it cools and is thus capable of holding less moisture. A Low, therefore, is usually accompanied by rain or snow if it has been traveling

over surfaces where it may gather moisture.

To take the place of the rising air in a cyclone area, winds move in from all directions. But these incoming winds do not move into the center of the cyclone.

On account of the rotation of the earth, any wind that starts toward the center of the cyclone area is deflected, in the northern hemisphere toward the right; in the south-



ern hemisphere toward the left. Since *all* winds blowing toward the cyclone area veer to the right of the cyclone center, they produce a great whirl in a direction opposite to the movement of the hands of a clock. (Figure 106.) In the southern hemisphere the cyclone rotates in a direction with the hands of a clock.

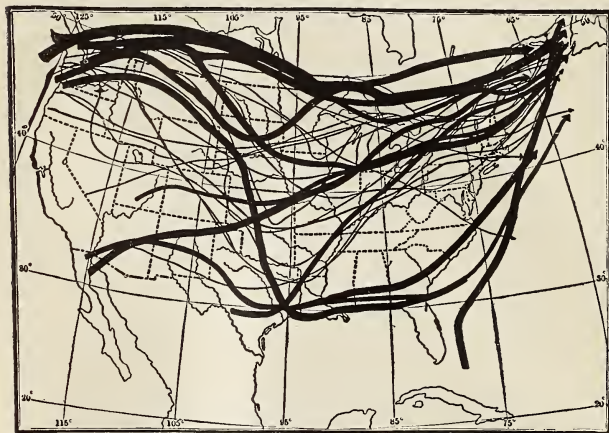
The Anti-Cyclone Is an Area of Clear Weather.—The anti-cyclone, or High, is just the opposite of a cyclone. The center of an anti-cyclone is a place of clear sky and high pressure. The anti-cyclone draws its supply of cold clean air from the inexhaustible upper stream of prevailing westerlies. This cold air is heavy and so it moves slowly downward and circles gently outward from the center of the High. The descending air of the anti-cyclone is also very dry, and as it falls to lower levels it increases in temperature, owing to adiabatic heating (page 192). As this dry air increases in temperature, it is capable of holding more moisture, and so the winds of a High quickly dry out the soils that the Low has moistened.

The approach of an anti-cyclone from the west is always heralded by a westerly wind, since the wind is blowing out from the center of the area of high pressure. Thus the westerly winds are nearly always the winds that bring us fair days and nights. In winter, when the difference in pressures between a High and a Low area is often very great, the west wind comes out of a High with a rush and a roar, often bringing a cold wave with a clear sky. Occasionally a winter High loops southward from Montana to Texas in 12 to 18 hours, bringing the dread "norther."

Paths of Cyclonic Storms Across the United States.—**Assignment.**—Obtain weather maps for at least five succeeding days. If you can obtain an outline map of the United States, mark on it the positions of the Lows for each succeeding day. If not, check these positions on any map of the United States with light pencil marks.

About how long does it take a storm area to travel from coast to coast?

In winter the *average* rate of motion of a cyclone across the continent is about 800 miles a day, while in summer it is only about 500. Occasionally a Low may move very sluggishly. On the other hand a winter storm from the southwest sometimes travels from Oklahoma to New York



PATHS MOST COMMONLY FOLLOWED BY CYCLONIC STORMS IN THE UNITED STATES
In this diagram, the width of the path indicates the proportional frequency of storms along that path.

in 36 hours. The velocity of the wind in the cyclone itself is also much greater in winter than in summer, since the difference in pressure between the high and the low areas is much greater. The changes in temperature as the storms pass are greater in winter than in summer, since the regions from which the northerly and the southerly winds flow in toward the center of low pressure vary more in their temperatures.

The accompanying map shows the paths of a large number of cyclonic storms across the United States. It will be seen from this that although these paths vary considerably, yet the general direction is a little north of east. The movement of cyclones is in the general direction of the prevailing westerlies of the middle latitudes.

Although the paths of cyclones frequently bend to the south as soon as they emerge from the Rockies, and may even reach the Gulf Coast, most of them ultimately leave the continent by way of the St. Lawrence Valley, or turn northward when they reach the Atlantic Coast and head toward the mouth of the St. Lawrence.

By far the greater number of our Lows originate over northern Pacific waters and enter the continent by way of Washington, Oregon, or British Columbia. Some originate over more southerly waters and reach the Gulf states or the Middle West by way of Arizona and New Mexico. A few have their beginnings in the Rocky Mountain Plateau.

The hurricanes that occasionally deal death and devastation to the Gulf Coast are Lows that come from the West Indies. These are smaller in diameter and more violent than our transcontinental Lows. They belong to the belt of the trade winds. They are borne westward on the wings of the trade winds into the Gulf of Mexico. Here they escape the influence of the trade winds, turn around to the north, and start east again along our Gulf Coast under the drive of the prevailing westerlies.

Weather Forecasting.—The data necessary for forecasting the weather are telegraphed to the Weather Bureau stations every day, and a record of them is placed on the weather map. The observations recorded on these maps furnish the forecasters with all the information obtainable as to what the weather of the future is to be. It

has already been said that the ruling cause of our weather conditions, in middle latitudes, is the eastward movement of cyclones and anti-cyclones.

If the direction and rate of motion of these can be determined the weather of those places which are likely to come under their influence can be foretold with a good deal of accuracy.

Thunderstorms.—There are two kinds of thunderstorms. One is the local thunderstorm, which may travel



A TREE COMPLETELY SHATTERED BY A STROKE
OF LIGHTNING

at most across two or three counties at the close of an extremely hot day. The other type is more severe. Thunderstorms of the second type may extend in an almost unbroken line for hundreds of miles and mark the end of a "hot spell" over a great area. In either case the thunderstorm is caused by the sudden meeting of a hot moist column and a cold column of air. The hot moist air is forced up by the inflow of cold air.

Condensation of moisture in the rising air

quickly forms clouds, and these become charged with electricity.

As the electrical charge increases, discharges take place which cause lightning flashes. These discharges occur

along the lines of least resistance and are often very irregular and forked. As tall objects are likely to offer good paths for the discharge, it is safest to keep away from trees and walls during a thunderstorm.

Tornadoes and Waterspouts.—Sometimes causes like those which produce a local thunderstorm are so strongly



EFFECTS OF A TORNADO

The iron windmill was blown across the cellar and protected the people who had fled there for safety.

developed that the indraft is exceedingly violent and a furious whirling motion is produced. The warm, moist air is whirled up rapidly and spread out into a funnel-shaped cloud with the vertex hanging toward the earth.

The cause of the whirling motion of the winds is exactly the same as in the cyclone (page 283), but the size of the whirl is small and the speed of the incoming winds is tremendous. Such storms are called *tornadoes*.

The reason why tornadoes occur chiefly during the spring is that the temperature contrasts are then greatest.

A body of very cold air may suddenly come in contact with a body of air over a small area that has become overheated. Result: the cold air rushes with overwhelming speed toward the center of the warm area, and a tornado is born.

The winds from all sides whirl in and whirl up so rapidly that a space is left at the center of the tornado almost



International Photo

A TORNADO

Notice the dust and débris that are being swirled toward the center of the storm.

without any air at all. Here the atmosphere pressure is so low that houses at the center of the whirl literally explode by reason of the normal pressure of air from the inside (page 179). This lightening of atmospheric pressure at the center of a tornado also accounts for straws being driven through wood and for many other freak happenings in a tornado.

These storms are often wrongly called cyclones. Both tornadoes and cyclones are whirls in the atmosphere. But the cyclone is a gigantic

whirl that travels for days clear across the continent and affects weather in any one place for as much as three days.

The tornado never lasts more than a few hours. Its work in any one place is over in a minute. The length of the path swept by it is rarely over thirty or forty miles

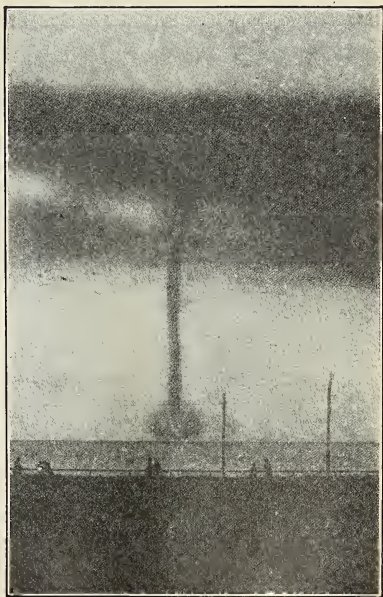
and the width generally less than a quarter of a mile. The rate of progress of a tornado in the Mississippi Valley is from twenty to fifty miles an hour, usually in a northeasterly direction. When storms of this kind occur at sea, a water column is formed in the funnel-shaped part of the storm and they then receive the name of *waterspouts*.

Rainfall of the United States.—

The distribution of rainfall in the United States can readily be divided into four belts which, although gradually shading from one into another, are yet quite distinct. These belts may be called the north Pacific slope, the south Pacific slope, the western interior region, and the eastern region.

In the north Pacific coast region the storms of the “westerlies” are common, particularly in winter, when the cyclonic movements are strong. The yearly rainfall here amounts to about seventy inches.

From central California south the rainfall of the Pacific slope decreases until, in southern California, there is almost



WATERSPOUT SEEN OFF THE COAST OF NEW
ENGLAND

no rain in summer and the entire rainfall for the year averages about 15 inches. The high-pressure area of the dry tropical calm belt moves sufficiently far north in summer to take this region out of the influence of the wet westerlies and into that of the drier belt.

The western interior region, extending from the Cascade and Sierra Nevada mountains to about the 100th



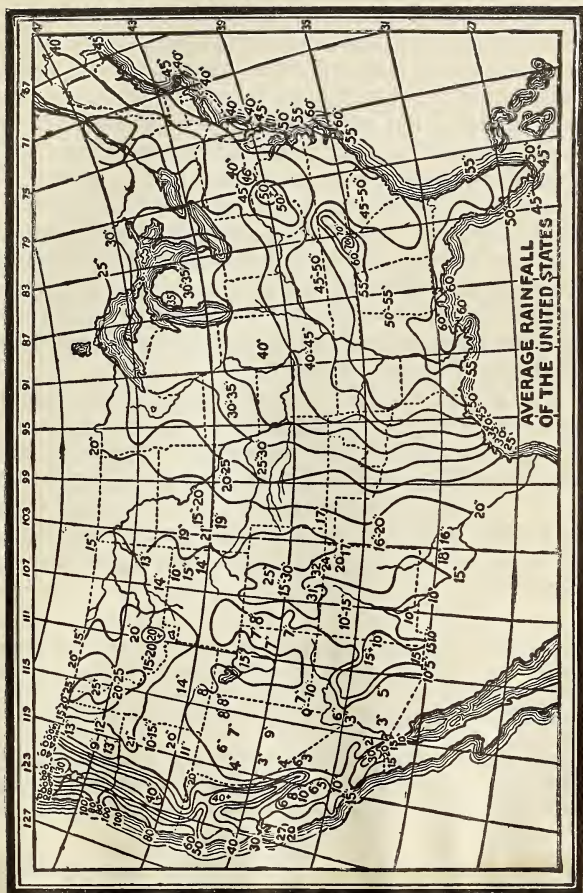
COMMON RAIN GAUGE

A funnel-like receiver conducts the rain into an inner tube of small diameter. This makes measurement easier when only a light rain has fallen.

meridian, is dry over the larger part of its surface, since the winds have deposited most of their moisture in passing over the mountains in the west (page 277). On the mountains and high plateaus, however, there is a considerable fall of rain, as the winds are cooled sufficiently in passing over these to deposit their remaining moisture. The fall of rain on the mountains and high plateaus supplies rivers of sufficient size to furnish water for extensive irrigation.

From about the 100th meridian to the Atlantic Ocean there is a varying rainfall, but it is as a rule sufficient for the needs of agriculture. It gradually increases toward the east, moisture being supplied plentifully from the Gulf of Mexico and the Atlantic Ocean by the southerly and easterly winds. The rainfall is well distributed throughout the year and averages from thirty to sixty inches.

Weather-lore.—"Some are weather-wise, some are otherwise," as Poor Richard said in his almanac. But Poor Richard speaks charitably. *Most* people are other-



wise. A great many of the commonly repeated weather maxims are based on superstition or hearsay.

Nobody has ever found any possible means of foretelling more than two or three days in advance what the weather is going to be. Yet many people cling to the old superstition that there will be six weeks more of winter if the ground-hog sees his shadow on the second of February. Years of observation have shown that there is no relation of any sort between a sunny or cloudy second of February and the character of the following two months of weather.

"If March comes in like a lion, it will go out like a lamb," is another of the proverbs that mean nothing. There is no whit of information of any kind that can be had on the first day of March to indicate what the weather will be on the thirty-first of the month.

We learned (page 31) that the position and shape of the moon in the sky are determined only by the relative movements of the earth and the moon. Yet many a false weather prophet believes that "a dry moon lies on its back." This is based on the old superstition that when the crescent moon lay "on its back," it would hold water like a saucer! But when the crescent was tipped or overturned, the water would spill!

Voluntary Project.—To test the reliability of certain weather signs.—Careful observation of sky and clouds for centuries, of air conditions, and of the behavior of birds, barnyard fowls, and insects has resulted in a number of weather maxims that are pretty reliable.

Refer to any of the books listed below and report the most dependable weather lore to the class. Let each pupil center his attention on one or two of the weather signs and report from time to time on the reliability of these old sayings.

Reading the Weather, T. M. Longstreth (Macmillan).

American Boys' Book of Signs, Signals, and Symbols, Dan Beard (Lippincott).

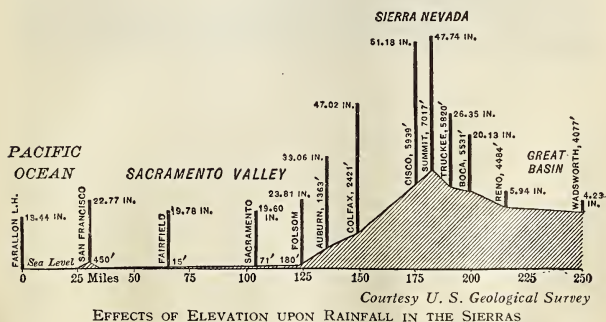
Official Handbook, Boy Scouts of America.

IV. CLIMATE

Voluntary Project.—After you have studied the following unit of work, prepare a brief report on the features that influence climate in your locality. If there are winds or climatic conditions peculiar to your region that you cannot understand, write the United States Weather Bureau for information. This Bureau is a great educational agency.

Climate is the average weather of a place or region. Two places may have the same average temperature throughout the year without having the same climate, since in one the temperature may be quite uniform and in the other very high at one season and very low at another. Many factors such as latitude, altitude, nearness to bodies of water, and ocean currents have a determining effect on the climate of any one place.

Effect of Mountains on Climate.—All over the world where people have the money and the leisure they are



accustomed to go either to the mountains or to the seashore in summer in order to get where it is cooler. They might for the same purpose travel northward in the northern

hemisphere, but they would need to go many times as far to get the same fall of temperature.

In summer one must ascend a mountain on an average about 300 feet vertically to get a mean fall of 1° F., whereas one must travel over 60 miles north to get the same change. In winter one must ascend farther on the mountain and travel not so far north, to get a change of a



TOP OF PIKE'S PEAK IN SUMMER

Notice the snow, and the rocks broken up by freezing water.

degree. As one ascends a mountain it grows colder and colder. In ascending a high mountain in the tropics one passes through all the changes in climate which one would pass in going from the equator toward the poles.

High mountains also affect the climate of the country near them. The windward side of mountains is moist, since the moisture in the air is condensed in rising over them. On the lee side the country is dry, as the air which moves over it has already been deprived of its moisture.

The country on the lee side will also be subject to hot dry winds like the *chinook* winds of the eastern Rockies

and the *foehn* in Switzerland. As the moist winds pass over the mountains their moisture is condensed. This raises their temperature so that it is above what it would normally be at the altitude reached. As these winds come down on the lee side of the mountain, the air is compressed and thus heated (page 192) so that on this side it is considerably warmer at the same altitude than on the windward side. A Montana chinook has been known to raise the temperature 40° in fifteen minutes. Thus high mountains affect not only the rainfall, but the temperature changes of the region round about.

Effect of Ocean Currents on Climate.—Circulating around each ocean there is a continuous drift of surface water extending to a depth of from 300 to 600 feet and varying in rate from a few miles up to fifty or more miles a day. In fact these rotating currents are the chief natural basis for the division of the oceanic area into six oceans, as our geographies generally divide them.

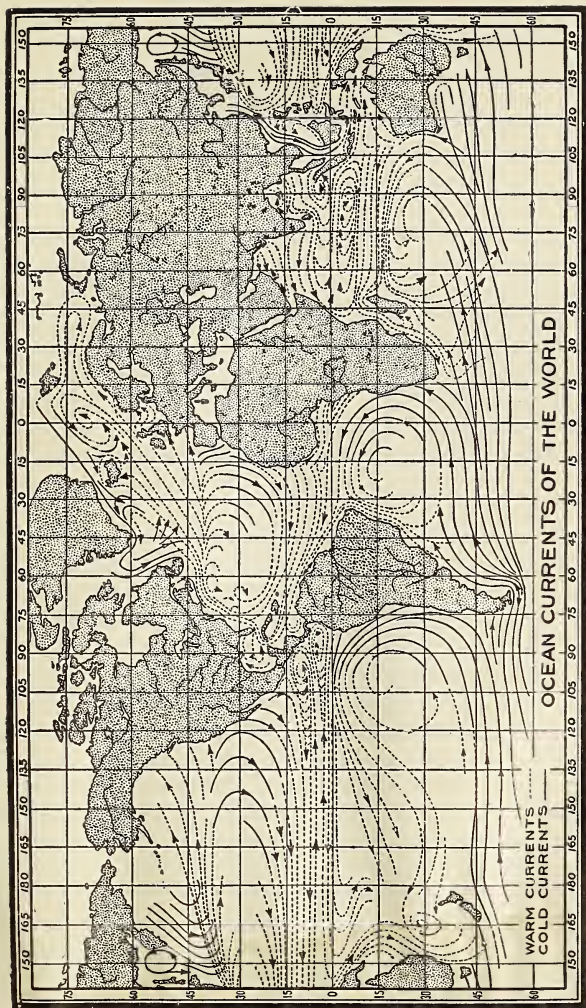
The temperature of winds blowing from the sea is modified by these currents and greatly affects the habitability of the earth for man. The editor of the National Geographic Magazine makes the striking statement that "the Gulf Stream carries enough heat toward Europe every twenty-four hours to melt a mass of iron as large as Mount Washington." Hammerfest at 71° north is a flourishing seaport, but there are no important settlements above 50° on the western side of the Atlantic. Alaska, the prevailing winds of which are warmed by blowing over the warm ocean, is a region which promises much for human habitation, while the region on the opposite side of the Pacific must remain almost destitute of human inhabitants. It should be noted that the effect of the warm ocean waters would be slight, except along the coast, were it not for the air movements.

Effects of Large Bodies of Water on Climate.—We have learned that dark, rough surfaces absorb heat more rapidly than smooth, light, highly reflecting surfaces. We have also learned that a great deal of heat is required to raise the temperature of water one degree—nine times as much as is required to accomplish the same result with an equal mass of iron. It is not surprising then that land surfaces heat up much more rapidly than water surfaces. How much more rapidly cannot be stated except on an average, because soils differ greatly from one another. The darker or the coarser the soils, the more rapidly they absorb heat.

There is another very important difference between the heating of land and of water by the sun. As we have seen, the rays of the sun penetrate to a greater depth in water—especially clear water—than in soil. In addition to this, the water is constantly in motion and is communicating the heat from the surface to the cooler waters below. Thus the summer's heat affects the water many feet below the surface. This makes a lake or sea a veritable storage tank for summer's heat, yet the distribution of heat through the waters beneath keeps the surface waters relatively cool in summer.

The land, on the other hand, receives all of the sun's heat upon its surface. The top few inches of soil heat up very rapidly every summer's day, but soil immediately below this shallow crust never becomes very warm, and does not show appreciable changes of temperature except with the changing seasons. At a very few feet below the surface the soil maintains a steady temperature summer and winter.

Surfaces that absorb heat rapidly also radiate it rapidly. A large percentage of the heat that the soil has absorbed during the day is given out to the atmosphere at night. But the water, slowly storing heat during the warm months and just as slowly giving it out during the cold months,



has a steadying effect upon the climate of the land adjoining. On some islands of the sea, the change of temperature throughout the year is almost imperceptible, whereas in the interior of continents the average temperature of some of the summer months is more than a hundred degrees higher than that of some of the winter months.

Day and Night Effects along a Shore.—In the summer, the morning sun heats the soil increasingly until, by reflection and radiation from the land surface, the atmosphere above it is highly heated and expanded. The cooler air flows in from the lake or sea and displaces the lighter warm air. If the sun continues to shine, this landward breeze persists until late in the afternoon; but its effect is seldom felt many miles inland. At night when the rapidly cooling soil reaches a temperature below that of the water, the direction of the breeze is reversed.

Summer and Winter Effects along a Shore.—During the summer in warm climates, a large body of water is heated much less rapidly than the moist air above it and so it absorbs heat from the air day and night. This cools the atmosphere, and cooled air currents from above the water temper the heat of the adjoining land.

During the winter the water gives up its heat more slowly than the atmosphere. As it gradually yields the heat it absorbed during the summer, the air above it is warmed, and currents of this warmed air modify the temperature of the adjoining land. For these reasons a large body of water slows up the approach of warm weather in spring and of frosty weather in autumn.

In middle latitudes where the prevailing winds are westerly, these effects are naturally much more marked and dependable on the east shore of a body of water than on the west shore. In many places on the east shores of large

lakes, delicate fruits can be raised because the steadying effect of these bodies of water prevents early "warm spells" alternating with frosts in spring, and delays the autumn frosts until the fruits have ripened. The tempering effects of warm ocean currents, combined with prevailing westerly winds, account for the mildness of climate even in high latitudes along the west *coasts* of North America and Europe, which are the east *shores* respectively of the Pacific and Atlantic oceans.

SUMMARY

A study of weather and climate involves much that we have learned about heat, air and water, together with certain effects of the rotation of the earth on its axis and of its revolution about the sun.

The earth's atmosphere acts both as a blanket and as a sun-shield to the earth's surface. The moisture and dust that are always in the atmosphere are responsible for its efficiency in these respects.

The axis of the earth is inclined $23\frac{1}{2}^{\circ}$ to a line drawn from the center of the earth to the sun. For that reason our days and nights vary in length during the year, because in summer the northern hemisphere is inclined toward the sun, and in winter away from it. The amount of heat received from the sun is not dependent upon our distance from it, but upon the directness of its rays. Since in summer the northern hemisphere is turned so that it receives the direct rays of the sun, more heat is absorbed by that hemisphere than during the winter, when the rays of the sun strike it slantwise. Thus the inclination of the earth's axis to the plane of its orbit and the revolution of the earth around the sun are responsible for our changes of seasons.

The atmosphere is the circulatory medium of the earth, without which there could be no life. Wind and all

movements of air are caused by unequal heating, and consequently unequal atmospheric pressure at different places on the earth's surface.

Some part of the torrid zone is always receiving the vertical rays of the sun. Thus the air in this belt of greatest heat of the earth is being constantly warmed and forced upward by cooler winds coming in from the north and the south. The heated belt where the winds are being forced up is called the doldrums. The cooler winds which come in from the north and south are called the trade winds. Because of the rotation of the earth, these trade winds do not blow directly north and south toward the equator, but are deflected toward the west.

The warm air which rises in the doldrums loses its heat and its moisture. When it reaches a considerable height it spreads out and flows both north and south toward the poles. Because of the revolution of the earth, these upper currents of cool air take on an eastward trend. When they reach the latitude of 30° to 35° on each side of the equator, the heavy dry air begins to sink to the surface of the earth. Here is a dry region of calms called the horse latitudes. The remainder of the air from the doldrums continues its journey toward the poles at a height of about three miles above the surface of the earth. The broad belt where the upper currents move eastward and slightly northward toward the poles is known as the belt of prevailing westerlies.

The changes of weather in the belt of prevailing westerlies are only remotely connected with the upper currents. The movements of air in the atmosphere beneath them are responsible for our changes of weather. In the atmosphere that lies closest to the surface of the earth, tremendous whirls of high and low barometric pressure travel across the country under the drive of the prevailing westerlies. A whirl of low pressure, called a cyclone, is a storm

area. A whirl of high pressure, called an anti-cyclone, is an area of clear weather. These eastward moving cyclones and anti-cyclones are responsible for most of the various changes in our weather. The two chief factors that enter into the forecasting of weather in middle latitudes are the direction of movement and the rapidity of movement of these High and Low areas.

Brief rain storms accompanied by lightning are called thunderstorms. They are caused by the sudden meeting of a hot moist column and a cold column of air. When the difference in temperature between these columns of air is very great, the heavy cold air rushes under the light warm air with such terrific speed that updrafts become exceedingly violent, and tornadoes on land or waterspouts over the ocean may result. The rainfall in different sections of the United States varies greatly. On the north Pacific slope there is a rainfall of about 70 inches a year. The south Pacific slope has an average rainfall of about 15 inches. The eastern slope of the Rockies is very dry, and the Mississippi Valley and the country east of it have a rainfall of from 30 to 60 inches.

The most commonly quoted weather maxims are unreliable, but there are some weather signs based upon the appearance of the sky and clouds and upon the behavior of animals and insects that are fairly reliable.

Many factors enter into the making of a detailed statement of climate for any one place. Latitude, altitude, nearness to large bodies of water, ocean currents, and kinds of soil are some of the factors upon which climate depends.

QUESTIONS

- How does the atmosphere act as a sun-shield? As a blanket?
- What would happen to life on earth if there were no atmosphere?
- What causes days and nights of varying length?
- What is meant by daylight saving?

What is responsible for our changes of seasons?

What one main cause is responsible for all the movements of the atmosphere?

What are the doldrums? The trade winds? The horse latitudes? The prevailing westerlies?

What is the effect of the earth's rotation on north and south winds?

What is the relation of prevailing westerlies to our weather?

What is a Low? A High?

What is the general direction of cyclonic storms across the United States?

What are the two chief factors that enter into forecasting the weather?

What conditions are mainly responsible for thunderstorms, tornadoes and waterspouts?

What are the main factors that enter into a statement of climate for any one place? Tell how each of these factors affects climate.

CHAPTER XII

STORY OF THE ROCKS AND SOILS

*And this our life, exempt from public haunt,
Finds tongues in trees, books in the running brooks,
Sermons in stones, and good in everything.*—Shakespeare.

It is believed that the whole surface of the earth originally hardened from a molten condition, just as lava from a volcano hardens when it cools. Such a surface could support neither plant nor animal life. And so long ages must have elapsed, bringing slow but tremendous changes, before conditions became favorable for the support of life.

We have already learned some things about heat, air, oxygen, carbon dioxide, the work of running water, solutions, atmospheric moisture, evaporation and condensation. These studies we have made will enable us now better to understand how the earth has been shaped, how its rocky surfaces were pulverized into soils, and how again and again soils have been rebuilt into rock and reground into soils.

Changes in the Earth's Surface.—The surface of the earth is constantly changing. In fact change is the fundamental law of life. There are forces constantly building up and other forces just as steadily tearing down. Sometimes the same forces are doing both. It is impossible to tell which set of forces is of the greatest service to man because without either, life could not continue. These

forces, alternately building and tearing down, have been at work ever since the earth's crust began to form.

I. THE TEARING-DOWN FORCES

Review.—We have seen that the waters of the sea and the waters that run over the land are wearing away the rocks, grinding them together, pulverizing them, and carrying the wreckage to other places (pages 200–205). This eroding must have begun as soon as the earth's crust became cool enough for the waters of the atmosphere to condense.

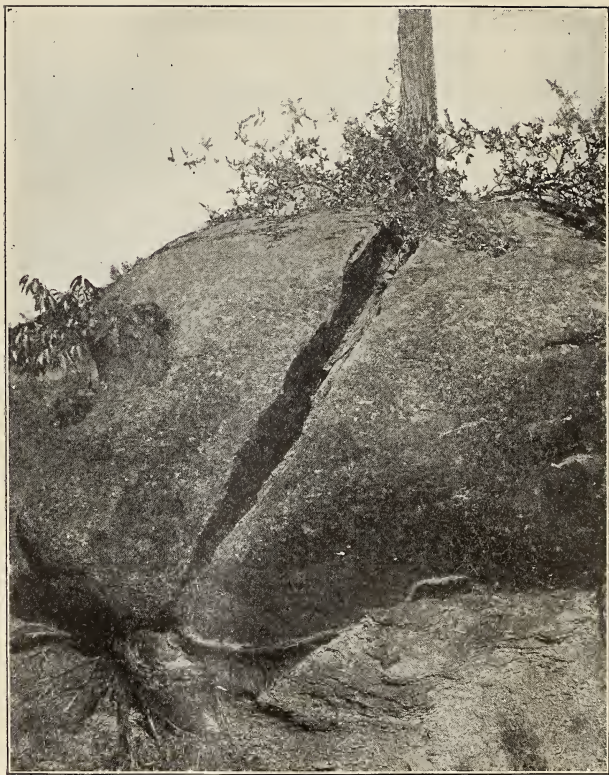
It is necessary, however, to take into account more than the power of water “to wear away the stones.” Water, especially when it has passed through decaying vegetable matter, has the power of dissolving some rock minerals. It may hold such substances in solution and carry them away to places where the water is evaporated and the dissolved substances deposited (page 225).

Water getting into the cracks of rocks and expanding when it freezes splits them apart and aids much in their



CLEOPATRA'S NEEDLE, CENTRAL PARK, NEW YORK

This shaft of stone had stood for 3000 years in the dry climate of Egypt without losing the distinctness of its carving. Yet within a year after it was brought to the moist and changeable climate of New York, its surface had to be covered with a preservative substance.



ROCK SPLIT BY THE GROWING ROOTS OF A TREE

destruction (page 199). Plant roots penetrate into the crevices of rocks and by their growth split off pieces of the rock.

Where the temperature varies greatly between day and night the expansion and contraction due to the heating and

cooling sometimes cause a chipping off of the rock surfaces. The outer layer of the rock is alternately greatly heated and greatly cooled, while the interior of the rock remains at about the same temperature. The repeated expansion and contraction of the surface layer eventually cause it to scale off (page 109).



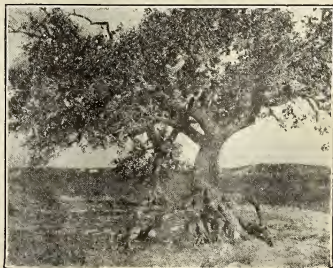
WIND-CUT ROCKS, GARDEN OF THE GODS,
COLORADO

These rocks have been fantastically cut by wind-blown sand.

are the chief weathering agents of the atmosphere. They work together, as we have seen (page 65), to cause the rusting of iron. Certain minerals of which rocks are composed change when exposed to the air somewhat as iron does when it rusts.

Wind Erosion.—
The artificial sand-

Oxygen, carbon dioxide, and moisture



A TREE BEING DUG UP BY THE WIND

blast is in common use. In it a stream of sand is driven with great velocity upon an object which it is desired to etch. In nature the same kind of etching is done by the wind-blown sand.

The glasses in the windows of lighthouses along sandy coasts are sometimes so etched as to lose their transparency. Rocks exposed to the winds are carved and polished; the softer parts are worn away more rapidly than the harder parts, just as in all other forms of erosion. In certain regions where the prevailing winds are in one direction, one side of exposed rocks is found to be polished, while the other sides remain rough.

Soils Produced by Decay.—All the agencies we have discussed and still others have contributed to breaking down the rocky crust of the earth into soil, thus preparing the way for plant life. The very plants themselves and the animal life which they support must die and return to the soil from which they came. If it were not for this the earth would eventually be encumbered with the dead forms of plants and animals; and the substances of which these bodies are composed would eventually be exhausted from the soil. Thus even decay may be looked upon as a process friendly to man.

Decay is a very complex process. It is produced by forms of life so small that they can be seen only with a microscope. There is good reason to believe that there are forms so small that even the most powerful microscopes will not reveal them. The most important of these minute forms of life are called *bacteria*. They exist in uncountable millions almost everywhere. Scientists are acquainted with over 1500 different kinds of bacteria, and each kind has its own peculiar characteristics. Molds and yeasts are other low forms of life that help in the processes of breaking down, or disintegration.

All these minute forms of life must have considerable moisture and some of them, at least, must have free oxygen in order to thrive and to accomplish their work. Almost every one who has walked through the woods has noticed how much more rapidly damp wood decays than dry wood. It is to keep moisture and air from wood that we paint it, so that bacteria may not have in it living quarters favorable to their work of destruction.

II. THE STORY OF THE ROCKS

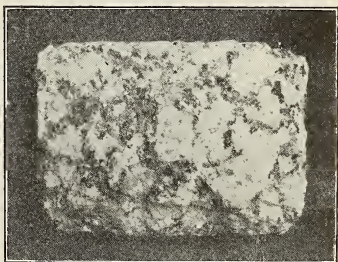
How Different Kinds of Rocks Were Formed.—The composition of different land areas varies greatly. Many different kinds of rocks are often found crowded together, or it may happen that the same kind of rock covers a large area. There is no uniformity.

The great variety of rocks of which the crust of the earth is composed has been divided into three great groups in accordance with the manner

in which they were formed. These groups are *igneous*, *sedimentary*, and *metamorphic*.

Granite, basalt, lava, and obsidian are examples of *igneous* rocks. The meaning of igneous becomes clear when we know that it is derived from the Latin word for fire, *ignis*.

The *igneous* rocks are those which have solidified from a melted condition. They may have solidified deep down within the crust, or on the surface, or somewhere between the depths and the surface.



GRANITE

Igneous rock formed deep below the surface of the earth.

Although granite and other igneous rocks are very slow to weather, ages of exposure will reduce them to soil and sand. We have seen (page 205) that the ocean is the goal of much of the waste which the rivers carry away from the uplands. The sand and mud carried out to sea and spread out over the ocean-floor are called *sediments*. Through long periods of time, conditions alter greatly, and so at one time layers of sand, at another time, layers of mud or silt may be deposited on the same ocean floor.



STRATIFIED ROCK

These layers have remained horizontal as originally formed.

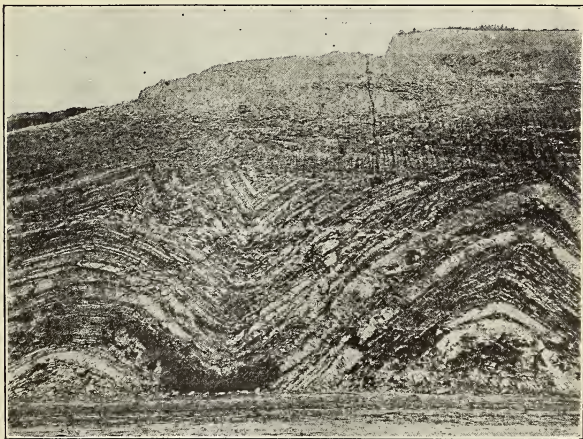
In the age-long periods of time that go to make up geological history, such layers of sediments have been changed into layers, or *strata*, of rock. Such rocks are called *sedimentary* rocks.

In sandstones, for example, the grains of sand have been compacted together, partly by the weight of the overlying water and partly by the action of mineral matter in the ocean water. Mud deposits are compressed into a rock called shale. The shales are finely stratified, often having many layers in an inch of thickness. The sandstones and shale are formed of the wreckage of the land surfaces.

The chalk cliffs of England and the limestone quarries of Indiana are alike in being sedimentary rock that ages ago was laid down under the sea. But chalk and limestone are of animal origin. They consist chiefly of shells of an ocean creature smaller than a pinhead, the *Globigerina*.

About four-fifths of the land surface of the earth is composed of sedimentary rocks. They vary greatly in color, durability, and usefulness to man.

Metamorphic rocks are modified forms of either the igneous or sedimentary rocks. The original igneous or sedimentary rocks have been subjected to forces, such as heat



SEDIMENTARY ROCK LAYERS THAT HAVE BEEN FOLDED BY MOVEMENTS OF THE EARTH'S CRUST

and pressure, that have produced physical and sometimes chemical changes in them.

Marble is crystallized limestone, and gneiss is generally a metamorphosed granite. Slate and mica-schist are greatly changed clay rocks, and anthracite coal is a metamorphosed form of bituminous coal. The rocks of this group are often hard to distinguish from igneous rocks.

Wherever we find sedimentary rocks, we know that the area was once under the sea, and that it has been lifted up by movements of the earth's crust. Some of the rocks

lie nearly in the condition in which they were originally formed, while others have been folded and warped and twisted.

The folding and warping of the rock layers, as shown by the picture on page 309, has brought some of the stratified beds which were originally horizontal into an almost vertical position, so that we now find at the surface the worn-off edges of these beds. Vast layers of rock at the surface of the earth have been worn away and removed, and thus rocks which were once at great depths below the surface have been exposed. Even granite rocks which were originally formed at a depth of thousands of feet below the surface now appear at the surface and are being quarried in many places.

The Origin of Coal and Oil.--Bituminous coal is sedimentary rock, formed from plants of ages ago which have been compressed and solidified by enormous and long-continued pressure.

We have learned that warm, moist air is necessary for the activities of the bacteria of decay. Where there is too much water and not enough air the conditions are not favorable for complete decay. When plants die and fall into water, they undergo changes but not the changes that occur in air. Most of the carbon, which in the air would be oxidized into carbon dioxide, is preserved under water.

Where vegetation grows, dies, and falls into water year after year for great lengths of time, the plant remains will gradually accumulate until they fill the swamps in which they have grown or the lakes which they have bordered. This explains the formation of great peat-bogs in Ireland and in other parts of the world. Some of the peat-bogs of Ireland are more than forty feet deep, and the spongy peat when cut and dried furnishes the most widely used

fuel of that country. That such bogs are filled lakes or swamps and that it has taken thousands of years for the peat to accumulate, is shown by the fact that hollowed logs used as canoes by prehistoric men are sometimes found buried in the peat at a depth of thirty feet or more.

If these peat accumulations should at some time be grad-



DIGGING PEAT IN IRELAND

ually submerged and covered with sand and silt, the ever-increasing pressure of the water and of the layers of sediment would gradually compress the spongy mass of vegetation into compact layers. In the course of ages these layers would harden and change into seams of bituminous (soft) coal. The overlying layers of sand and mud would change into layers of sedimentary rock. A coal layer is

probably of about one-fifth the thickness of the peat-bed from which it originated.

Most of the seams of coal were laid down thousands and thousands of years ago in what geologists call the Carboniferous Age. The gloomy jungles and dense undergrowths of that age contained trees and plants wholly



Courtesy of Taylor Coal Co.

COAL MINING IN SOUTHERN ILLINOIS

Using a pneumatic drill, preparatory to blasting. Notice the horizontal layers in which the coal lies.

unfamiliar to us. Giant club-mosses and ferns with woody tree-like trunks grew to a height of from fifty to seventy-five feet. Dense thickets of jointed-stemmed plants like bamboo shot up to a height of forty feet. More lowly ferns thickly carpeted the ground. Tropical conditions prevailed; and these jungles of ferns and club-

mosses quickly attained their maturity and gave way to new growths.

It is probable that most of the ancient forests were in swamps near the sea, like the Florida Everglades. The land gradually sank, the layers of vegetation were covered with water and then by deposits of sand and mud. Later the land may have risen, another dense jungle may have sprung up on the site, only to be submerged again and covered with sediment.

This process has been repeated many times in the history of the earth. In sections where it has happened more than once over the same area, as described above, it has resulted in the formation of several seams of coal, one above the other, with layers of sedimentary rock between. If in after ages such seams of coal were heated by the folding of the earth's crust, or by some other means, the bituminous coal was changed into anthracite (hard) coal.

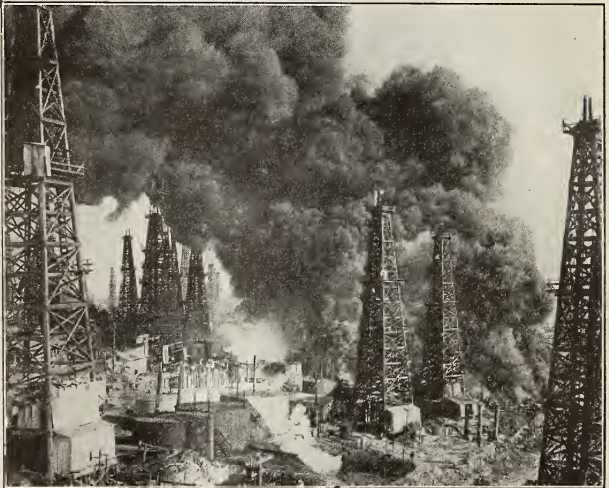
Sometimes miners find the roots of ancient trees, now changed into coal, projecting from the bottom of a seam of coal into the underlying rock layers that formed the soil in which this ancient vegetation grew. Sometimes the impressions of leaves and plant stems are found in the underlying or the overlying rock layers and even in the coal itself.

Petroleum is probably the result of the decomposition of animal and plant remains which have been subjected for ages to heat and enormous pressure. By distilling petroleum, or crude oil as it is generally called, many different products are obtained, among which are gasoline, kerosene, benzine, paraffin, and various lubricating oils.

The crude oil itself is burned in many sections to produce heat and power. For many purposes it is better than coal. The supply of oil seems to be much more limited than that

of coal, but it has been wasted at times fully as recklessly. In the interest of future generations, both coal and oil should be more carefully conserved.

The Story of Ancient Life Found in the Rocks.—If the body of a dead animal falls into the sea or into a swamp it may be covered with sediment before its skeleton rots away. The sediment may be turned to rock and the bones



International Photo

SIGNAL HILL OIL FIELDS NEAR LONG BEACH, CALIFORNIA

This picture was taken during a fire which did one hundred thousand dollar's worth of damage, and was conquered only after twelve hours of fighting.

of the animal gradually be dissolved away, but the mould of the skeleton will often be left in the rock. Such impressions are called *fossils*.

As the rock layers of the earth are explored, fossils of different kinds of plants and animals are discovered. The

fossils of the more recent rock layers correspond very closely to the plants and animals that are found upon the earth to-day, but the older the layers, the less they correspond. A fragmentary record of ancient plant and animal life is engraved upon certain of the sedimentary rocks. Rocks which were formed under different conditions contain different species of life-forms, showing that throughout all time the geographic condition has had a marked influence upon plants and animals.

The rocks and fossils also show that the geographical conditions of certain areas have varied greatly. Some regions have been below and above the sea several times. Regions now cold have been warm, and those now dry have been wet, and *vice versa*. Thus the life in certain areas has suffered great changes by the geographical accidents to which the region has been subjected. The petrified forests near Holbrook, Arizona, show some of the most remarkable tree fossils ever found and indicate that the region has been subjected to remarkable geographical changes. In this case, the wood of the ancient trees has been replaced, molecule by molecule, by a flinty material



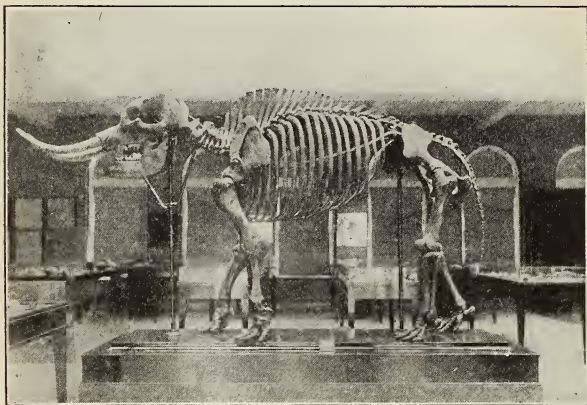
FOSSILS OF ANCIENT SEA SHELLS

These fossil impressions are in limestone.

akin to quartz. The same thing has sometimes happened to the bones of ancient animals.

III. TRANSPORTATION OF SOILS

Local and Transported Soils.—Wherever the inclination is not too steep, we find the surface of the bed rocks covered for varying depths with soil. In some places it grows coarser and coarser the farther down we dig. The



SKELETON OF AN ANCIENT AMERICAN ELEPHANT

Found near Los Angeles, California.

coarser the pieces become, the more they resemble the bed rock, until finally they pass by imperceptible stages into it.

From this we conclude that the solid underlying rock once extended to the surface. Through long periods of time, weathering agents have been splitting, grinding, changing, pulverizing, dissolving the rock substances until the upper layers of rock have been reduced to soil. This kind of soil is called *local* or *sedentary* soil.

In other localities the coarseness of the soil does not materially change as we dig into it, but suddenly we come upon the surface of the bed rock, which may contain few, if any, of the constituents which were in the soil. Our only conclusion in such cases is that some powerful agency has transported these soils from other regions and deposited them where they now lie. This soil, which in no way resembles the underlying rock, is called *transported soil*.



PETRIFIED TREES

Found near Holbrook, Arizona.

Water as a Carrier of Soils.—Review.—We have seen that water is a very important agent in the transportation of soils. It is constantly busy tearing down the uplands and building up the lowlands. Review briefly pages 200–205.

Wind-borne Soils.—We know that winds carry dust but we seldom think of them as carrying soils in great amount. Yet there are many regions where the winds have been the chief agents in building up the farming lands.

Whenever the wind blows over dry land, particles of dust and sand are blown away and deposited elsewhere. The interiors of our houses often become covered with dust blown from the dry streets. Even on ships at sea thousands of miles from land, dust has been collected.



LOCAL SOIL

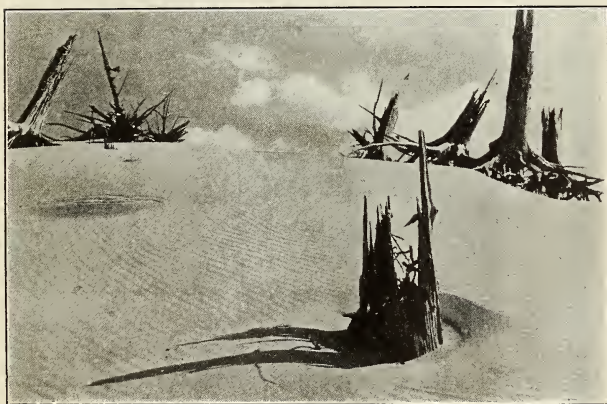
This soil has been weathered from the underlying rock.

Not many seasons ago, scientists were puzzled by a colored snow that fell in March over an area of probably 100,000 square miles in the north central and eastern part of the United States. Two professors at the University of Wisconsin proved that the color was furnished by dust blown from the plains of the Southwest, 1000 miles away. It is estimated that this March wind alone must have transported millions of tons of dust across the country.

In Kansas and Nebraska there are beds of volcanic dust, reaching in some places to a thickness of more than a score of feet, and yet there are no known volcanoes either past or present within hundreds of miles. In China there is a deposit of fine, dustlike material, in some places a thousand feet thick, which is thought by some to be wind-blown.

This forms a very fertile and fine-textured soil and supports a great population. Many of the inhabitants of the region live in caves dug in the steep banks of the streams, so firm and fine textured is the material. Wind deposits of this kind are called *loess beds*.

Ice as a Builder of Soils.—The agent that has had most to do with preparing the soils of the great grain-bearing



Courtesy Florence M. Carr.

FOREST CHOKED OUT BY WIND-BLOWN SANDS

Sand-laden wind generally deposits its burden in mounds and ridges called sand dunes.

When dunes once begin to form, they act as barriers to the wind and thus cause their own further growth. This picture was taken on the southern shore of Lake Michigan.

regions of Russia, northern Europe, Canada, and the United States is ice. It has worn down and pulverized the rocks into soils, has mixed and transported the soils from regions farther north, and has laid them down to form the fertile agricultural fields of these regions at the present day. Ice has been the master soil-builder of much of the tillable land of the world.

How Ice Does This Work.—In mountain regions where the snow holds over through the summer, the wind-drifts and the snow-slides carry great quantities of snow into the upper valleys, until ever-accumulating masses of snow and ice, hundreds of feet thick, are formed.

Although ice in small pieces is brittle, in great masses it acts somewhat like a thick and viscid (sticky) liquid. It



SNOW FIELDS AT THE HEAD OF A GLACIER

conforms itself to the surface upon which it lies, and under the pull of gravity or pressure from an accumulating mass behind, slowly moves forward, resembling in some ways thick tar creeping down an incline or spreading out when heaped into a pile. Such a moving mass of ice is called a *glacier*. As glaciers creep down the valleys, dirt and rocks fall upon their edges from the upper valley sides and are borne along upon the ice. If two glaciers unite to form a larger one, the débris upon the two sides which come together forms a layer of dirt and rocks along the middle of the larger glacier. At the end of the glacier this material which it has borne along is deposited in irregular piles of rock and dirt.

If a glacier extends over a region where the surface has

been weathered into soil, this fine material may be shoved along under the ice for great distances.

Continental Ice Mantles.—The whole of the island of Greenland is covered with a deep sheet of ice except a narrow border along a portion of the coast and the part of the island north of 82° , which has little precipitation. The extent of the ice sheet is nearly equal to the combined area of the states of the United States east of the Mississippi and north of the Ohio. The depth of the ice is not known, but probably in some places is at least several thousand feet. Although along the coast mountains rising from 5000 to 8000 feet are not uncommon, yet in the interior the thickness of the ice is so great that no peaks rise above it.



THE FIESCH GLACIER

If two glaciers unite to form a larger one, the debris which they have collected forms a layer of dirt and rocks along the middle of the larger glacier. Such a "medial moraine" is seen in this glacier.

The surface of the inland ice is a smooth snow plain. Extending from this ice field are huge glaciers having at their ends a thickness of from 1000 to 2000 feet.

Careful examination of all the surface formations over large areas of what are now the most thickly populated

regions of North America and Europe has led geologists to believe that at a former period in the earth's history, perhaps not more than a few thousand years ago, the northern part of both continents was covered with a thick layer of ice. Evidences of this ancient ice covering are seen in North America as far south as the Ohio River and extending over a vast region which now enjoys a temperate climate.



BOULDERS AND SAND LEFT BY A MELTING GLACIER

This mantle of ice after several advances and retreats finally disappeared, leaving the country as we now find it.

Although the border to which the ice extended and many of the changes which the ice made in the surface of the country have been carefully studied and mapped, yet the cause of this extension of the ice and the exact time at which it occurred have not yet been determined. Many theories have been brought forward to account for it, but none of them explains all the facts.

That the ice was here seems to be sure, but exactly when or why is unknown. This period when the ice was of great extent is called the *Glacial Period*. Probably during the earth's history there have been several of these periods, but to the last is due the great change wrought upon the present surface of the country and upon plant and animal life.



Courtesy U. S. Coast Guard

ICE PATROL VESSEL DESTROYING ICEBERG WITH TNT

When a glacier extends out into the sea, the water tends to float the ice. If it extends out into deep enough water, the buoyancy of the water will be sufficient to crack the ice, and the broken end will float off as an iceberg. Icebergs from the Arctic glaciers are a menace to summer shipping in the Atlantic. To get a notion of the real size of this iceberg, it must be remembered that eight-ninths of it is under water.

The greatest ice invasion during this period extended from northern Canada across New England into the sea, across the basins of the Great Lakes and the upper Mississippi Valley and across a part of the Missouri Valley. It wrapped in its icy mantle almost the entire region between the Ohio and Missouri rivers and the Atlantic Ocean.

What the Ancient Glaciers Did in North America.—The thickness of the ice over these central areas was very

great, probably approaching a mile. The pressure on the ground below must have been tremendous and the scouring and erosive effect vast indeed. The soil which previously covered the surface was swept away and borne toward the ice margin, leaving the rocks smoothed and bare.



AREA IN NORTH AMERICA COVERED BY THE ICE OF THE GLACIAL PERIOD

The traces left by these ancient glaciers are unmistakable. When a glacier melts, all the material which it has moved along under it as well as that which it has carried on its surface or frozen in its mass is deposited, forming

what is called ground moraine. North of the Ohio River and extending westward beyond the Mississippi and up into the Dominion of Canada is a region of rolling land with deep rich soil. This soil was probably deposited by the continental glaciers which once covered this vast area, and was spread out by the slowly moving ice or by water from the melting glacier.

Where a glacier has little load, as near its source, the bed rock is stripped bare, smoothed, polished, and scratched by the material which the ice has scraped over it and borne along. Here the soil that is left when the ice has retreated is very thin. Such is much of the country of New England and of eastern Canada.

SUMMARY

It is believed that the whole surface of the earth originally hardened from a molten condition. Long ages elapsed bringing slow but tremendous changes before conditions became favorable for the support of life. Heat, winds, oxygen, carbon dioxide, atmospheric moisture, water erosion, and decay have worked together to break down everything at the surface of the earth into soil.

Many different kinds of rocks are found but they may all be divided into three great groups—igneous, sedimentary, and metamorphic. Igneous rocks have solidified from a melted condition. Sedimentary rocks are made up of the wastes which the streams carry from the land and deposit in layers on the ocean floor, or from billions of tiny shells that have fallen to the ocean floor. These have been compressed through ages into rock. Metamorphic rocks result from igneous or sedimentary rocks having undergone further changes through additional heat or pressure.

Peat is composed of plant remains that have fallen into water and have gone through slow changes. Peat that ages ago was submerged under the ocean and sub-

jected to great pressure has been changed into a sedimentary rock called coal. Petroleum is probably the result of decomposition of animal and plant remains which have been subjected for ages to heat and enormous pressure.

Impressions of ancient plant or animal life found in sedimentary rocks are called fossils. Occasionally forms of ancient life are found which have undergone a change called petrification.

Soils that are found just where they have been weathered from the underlying rocks are called local or sedentary soils. Soils which show by their composition that they were not derived from the underlying rocks are called transported soils. These are so called because they have been transported by water, wind, or ice from where they were formed. All three of these agents have been instrumental in the formation of great areas of agricultural soil.

QUESTIONS

In what ways has water been responsible for tearing rocks down into soil? How has heat helped in this work? Oxygen? Carbon dioxide? Wind?

What is the cause of decay? Why may decay be looked upon as a process friendly to life?

What are the three great groups of rocks? How have they been formed?

What is the origin of peat? Of coal? Of petroleum? May coal be called a sedimentary rock?

What is a fossil? In what ways have these probably been preserved through the ages?

How has local soil been formed?

What agencies have been responsible for transporting soils?

What is a glacier? What is meant by the Glacial Period? How did the ice of this period build soils in some places and leave other areas bare? What great areas of agricultural soil in North America were built up by the continental glaciers? What areas were stripped of most of their soil?

CHAPTER XIII

THE RELATION OF SOILS TO LIFE

See dying vegetables life sustain,

See life dissolving vegetate again:

All forms that perish other forms supply.—Pope.

It seems strange that there should be even a remote relationship between the “everlasting rocks” and the live part of the earth. Yet the soil, which ages and ages of weathering and decay have produced, is the growing place of most plants and the homes of many animals.

Plant roots anchor plants to the soil, spreading into the soil, sometimes to surprising depth. They also take up necessary food elements and water from the soil and pass them on to the rest of the plant. Thus the soil furnishes home, food and drink to the higher forms of plant life.

Plants may serve as food for animals or for man. Plant-eating animals may in turn serve as food for meat-eating animals or for man. And so from the soil, either directly or indirectly, comes all our food. In like manner, the textiles for our clothing, most of the materials for building and furnishing our homes,—in fact, the necessities of life may be traced back to the soil.

Enumerate a half-dozen “manufactured” food products, and trace them back to the soil. Trace cotton, linen, wool, and silk back to the soil. Of course, building stones are quarried and metals are mined from the earth. Bricks, tile, glass, porcelain, etc., also have an “earthy” origin, but like the stones and metals, they are not the products of life and growth. Trace back to life and growth in the

soil carpets, tables, chairs, and other things that are used in the building and furnishing of our homes.

I. COMPOSITION OF SOILS

Kinds of Soil Particles.—Experiment 98.—Examine under a strong magnifying glass samples of sand, loam, clay, peat, and other kinds of soil. Notice the different kinds of particles composing the different soils and the shapes of these particles.

Experiment 99.—Put a handful of ordinary loamy soil into a fruit jar nearly full of water and allow it to stand for a day or two, shaking



SOIL PARTICLES (Greatly Magnified)

This photograph shows the relative sizes of soil particles. From left to right: clay, silt, sand, gravel.

occasionally. At the end of this time shake very thoroughly and after allowing it to settle for a minute, pour off the muddy water into another jar. Allow this to stand for about an hour and then pour off the roily water and evaporate it slowly, being careful not to burn the material left. Feel the texture by rubbing between the thumb and fingers, and examine with the eye and with a magnifying glass, the three substances thus separated. These three separates will be composed largely of sand, silt, and clay.

If a compound microscope (page 389) is available, mix a bit of the silt and of the clay in drops of water and put these drops on glass slides. Examine the drops under the low power of the microscope. Notice the little black particles of decayed vegetable matter, also the little bunches of particles that may still cling together. Why was it necessary to soak the soil so long? Draw the shapes of a few of the particles. Describe the composition of the soil you have examined.

Soils differ greatly in fineness, mineral composition, and waterholding capacity. They also differ greatly in the amount of decaying vegetable material in them. Some soils have practically none of this material. Others have a great deal of decaying vegetable matter mixed with the decomposed rock. In certain swamps and lowlands, soils are made up almost entirely of decayed vegetable matter, peat, and muck. The soil at the surface is usually finer than the soil a foot or so below the surface. The underlying coarser and lighter colored soil, which contains little if any vegetable matter, is usually called the *subsoil*.

If we examine most soils with a microscope, we shall find that they are composed, as was seen in Experiments 98 and 99, of many different kinds of material. Some of these materials dissolve slowly in water and thus furnish food for plants; others are insoluble.

In different soils the particles vary greatly in size as well as in composition. In gravel the particles are large and in a gram's weight there would be but few; in sands there are many more, dependent upon the fineness; in silt particles are still smaller. It would take 500 of the largest grains of silt laid side by side to extend an inch. Clay is much finer still. It would require 5000 of the largest clay particles laid side by side to reach an inch. In a gram of clay there are several billion particles.

Neither gravel, sand, nor clay alone makes a good garden soil. For general farm purposes, the best agricultural soil is a mixture of sand, silt, and clay, with some decaying organic (vegetable or animal) matter in it. Such soils, intermediate between sand and clay, are usually called *loams*. There are sandy loams and clayey loams, with many intermediate varieties. It must not be understood, however, that other soils beside the loams are worthless. Certain climatic conditions, as we shall learn, make sandy, and even stony soil useful for the raising of valuable kinds of crops.

How Nature Has Prepared Fertile Soil.—Decaying organic matter in the soil is called *humus*. In general, it may be said that the fertility of the soil depends upon the amount of humus in it. How humus gradually accumulated in the first soils weathered from the bare rocks may be understood from a knowledge of the *lichens*.

The lichen is one of the simplest forms of plant life. It may be called a partnership-plant since it is made up of two sets of very low forms of plant life, living together and dependent on each other. Each set of plants in the partnership has its own work.

The lichen may adhere to a bare rock, take up moisture and possibly some mineral plant food from its support. From this and from the carbon dioxide of the atmosphere, one set of partners manufactures the food for the lichen community plant. These lichens may endure drought, cold, cutting winds, long exposure to light, and many other conditions which higher forms of plant life cannot endure.

As generation after generation of these lichens grow and die, they add humus to the slowly forming soil. They also help in the weathering of the rocks. After long periods of time, enough humus and weathered soil collect to support higher forms of life. These in turn die and enrich the soil with more humus, thus preparing the way for still higher forms of life. And so it is clear that a naturally fertile soil is the product of ages of plant life and decay.

II. HOW PLANT ROOTS OBTAIN FOOD AND MOISTURE FROM THE SOIL

Water Film on Soil Particles.—Experiment 100.—Take about a quart of soil from a few inches below the surface of the ground and after sifting out the large chunks, put it in a sheet-iron pan and carefully weigh it to the fraction of a centigram. Place the pan contain-

How Plants Get Water From the Soil 331

ing the soil in a drying oven or ordinary oven, the temperature of which is but little above 100° C. The soil should be spread out as thin as possible. Allow it to remain in the oven for some time, until it is perfectly dry throughout. Weigh again. The loss of weight will be the weight of water contained in the soil. As there was no free water in the soil how was this water held? Dip your hand into water and notice how the water clings to it after it is withdrawn. Examine with the eye and the lens several particles of the original soil as taken from the ground and see if there is a water film on each of these as there was on the wet hand.

Experiment 101.—Take the soil that has been dried and weighed in the previous experiment and heat it throughout to a red heat over a Bunsen burner or in a very hot oven. Weigh again. If there is still a loss of weight this must be due to the burning of the organic matter—rotten twigs, roots, leaves, etc.—which was in the soil. Soils differ greatly in the amount of water they contain and in the amount of organic substance present.

We have seen from Experiment 100 how the soil takes up water, and how each little particle has a film of water around it. Little hairs on the plant roots are prepared to take up these little films of water which surround the soil particles. These water films have probably dissolved a minute amount of material from the soil particles, and this material enters into the plant and can be used for food.

Root-hairs Take up the Water Film.—**Experiment 102.**—Place three or four thicknesses of colored blotting paper on the bottom of a beaker. Thoroughly wet the paper and scatter upon it several radish or mustard seeds. Cover the beaker with a piece of window glass and put in a warm place. Allow it to stand for several days, being sure to keep the blotting paper moist all the time. When the seeds have sprouted, examine the rootlets, with a magnifying glass or low power microscope, for the root-hairs which look like fuzzy white threads. Touch the root-hairs with the point of a pencil. They cannot, like the rest of the root, stand being disturbed. On what part of the plant root do the root-hairs grow? As the blotting paper dries, what happens to the root-hairs?

Review the findings of Experiments 75 and 76.

Plant roots are enabled particularly by the little tube-like root-hairs (Figure 107), which were examined in Experiment 102, to take the film of water which surrounds the soil particles and carry this water to the stem and, through it, to the leaves. The water which the root-hairs take from the soil particles is a dilute solution containing the plant food substances. All plant foods must be in dilute solution before plant roots can appropriate them. Not only do roots absorb the water from the soil, but they secrete weak acids which aid in dissolving the mineral substances which the plants need. This can be seen where plant roots have grown in contact with polished surfaces, such as marble. These surfaces are found to be etched.



FIGURE 107



END OF PLANT
ROOT
Greatly magni-
fied

How Moisture and Food Enter the Root-Hairs; Osmosis.—Experiment 103.—Cut a potato in two. Dig out one of the halves into the shape of a cup and scrape off the outside skin. Fill the potato cup about $\frac{2}{3}$ full of a strong solution of sugar. Mark the height of the sugar solution by sticking a pin into the inside of the cup. Place the cup in a dish of water. The water should stand a bit lower than the sugar solution in the potato cup. After the cup has stood in the water for some time, notice the change in the height of the denser sugar solution.

FIGURE
108

Experiment 104.—Bore a $\frac{3}{4}$ -inch hole 3 or 4 inches deep in the top of a carrot. Scrape off the outside skin and bind several strips of cloth around to keep the carrot from splitting open. Fit the hole with a one-hole rubber stopper having a glass tube about 1 meter long extending through it. (Figure 108.) Fill the hole in the carrot with a strong sugar solution colored with a little eosin and strongly press and tie in the stopper. The sugar solution will be forced a short distance up the tube by the insertion of the stopper. Mark

with a rubber band the height at which it stands. Submerge the carrot in water, keeping the tube upright, and allow it to stand for a few hours. Mark occasionally the height of the column in the tube. Taste the water in which the carrot was submerged. There has been an interchange of liquids within and without the carrot.

The plant root takes up its water in the same way the water was taken into the sugar solution of the potato cup or of the carrot. The water or *sap* within the substance of the root is denser than the soil water, just as the sugar solution was denser than the water outside. It has been found that whenever two liquids or gases are separated by an animal or plant membrane, there is an interchange of the liquids or gases, the less dense liquid or gas passing through more rapidly. This is called *osmosis* and is of the greatest importance to both plants and animals.

All animals and plants are made up of exceedingly minute parts, called *cells*. Figure 114 (page 357) shows the cells in a leaf greatly magnified. The higher plants and animals are composed of vast numbers of these cells. The cell usually has a thin cell wall, which in living and growing cells incloses a colorless semi-fluid substance called *protoplasm*.

Protoplasm is the living part of the plant. It is found in all the cells where growth is taking place, where plant substances are being made, or where energy is being transformed. It has the power of dividing and forming new cells, and it is in this way that the plants grow.

The little root-hairs are composed of one kind of plant cells. Each root-hair cell has a thin wall lined with protoplasm. Enclosed within this film of protoplasm in each cell is a tiny bit of cell sap, a solution of various kinds of plant foods. The protoplasm of the cell acts as a living membrane through which osmosis takes place. Since the cell sap is denser than the soil water, more liquid moves

into the cell than from it. A little of the cell solution does move out, however, and it is this which helps to dissolve the soil particles.

How Sap Is Forced up the Stem.—Experiment 105.—Cut off the stem of a thrifty geranium, begonia, or other plant an inch or two above the soil. Join the plant stem by a rubber tube to a glass tube a meter long, of about the same diameter as the stem. See that the rubber tube clings strongly to both glass tube and stem.

It may be best to tie it tightly to these. Support the glass tube in a vertical position above the stem and pour into it sufficient water to rise above the rubber tube. (Figure 109.) Note the position of the water column. Thoroughly water the soil about the plant. Watch the height of the water column, marking it every few hours.



FIGURE 109

The water taken in by the roots passes on from cell to cell by osmotic action and rises in the stem in the same way that the water rose in the tube attached to the stem of the growing plant in Experiment 105. The cells in the roots become distended with water and protoplasm and thus exert an outward pressure. This root pressure, together with *capillarity*, will account for the rise of the sap in lowly plants, but the cause of the rise of the sap to the top of lofty trees is difficult to understand.

Roots extend themselves through the soil by growing at the tips. Here the cells are rapidly dividing, forming new cells, and building root tissue.

Class Project.—To transplant a tree, plant, or shrub.—Study the accompanying diagram (Figure 110) by Charles Lathrop Pack, President of the American Tree Association.

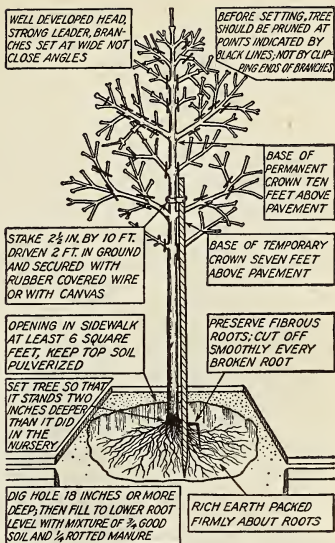
Select a good healthy tree or plant. Take it up with the least possible injury to the root-hairs. Do not touch the root-hairs nor allow them to dry out. In transplanting, follow the directions indicated in the diagram. Some root-hairs will of course be destroyed or

dried up. Is there any connection between this fact and the necessity for pruning a transplanted tree?

III. KINDS OF SOIL-FOOD NEEDED BY THE PLANT

Rock disintegration does not furnish all the complex materials needed for the growth of agricultural plants. Only the lower orders of plants, such as lichens, can grow on soil as at first formed.

The minerals composing the soil must furnish certain substances for the support of plant life. Many of these minerals are needed in such small quantities that most soils have an abundance of them.



Courtesy Nature Magazine.

FIGURE 110.—HOW TO TRANSPLANT A TREE

Experiment 106.—(Teacher's Demonstration.)—Fill three 2-quart fruit jars each about half full of distilled water. Add to the water in the first of these $\frac{1}{2}$ gram of potassium nitrate, $\frac{1}{4}$ gram iron phosphate, $\frac{1}{100}$ gram calcium sulphate, and $\frac{1}{100}$ gram magnesium sulphate. Add to the water in the second jar the same ingredients with the exception of the potassium nitrate. Replace this by potassium chloride. Add nothing to the water of the third jar. Put the jars where they will have plenty of sunlight and warmth; place in each a slip of *Wandering Jew* about 10 inches long. Note which slip grows the most thriftily. In the third jar there is no mineral food, in the first all the food that is necessary, and in the second all the necessary food except nitrogen. (Save the first jar and contents for Experiment 109.)

In Experiment 106, it was found that in the distilled water the plant made but little growth. Water and air alone are not sufficient. It did not thrive when the nitrogen was lacking, but grew very well when all the necessary elements were present. In most plants all the foods except carbon and a part of the needed oxygen are taken in by the roots. The soil elements that the plants must have are nitrogen, potassium, calcium, magnesium, phosphorus, sulphur, and iron. Water supplies hydrogen and oxygen; while carbon, another necessary element, is taken from carbon dioxide of the air. Nitrogen, phosphorus, and potassium are the soil elements that are used most freely by the growing plant.

Nitrogen is an element that enters into the structure of every living thing. No plant or animal growth or repair may occur without it because it is an essential element of the life substance, protoplasm (page 333). It does not build alone but it is indispensable in life-building processes. The element nitrogen is a gas that constitutes about four-fifths of the atmosphere. Yet the higher forms of plant and animal life can no more use the free nitrogen of the atmosphere than a human being can digest carbon. The nitrogen must be chemically united with other elements into compounds that are soluble in water before the plant can make use of it for food.

The two other elements that are much needed by plants and that are soon exhausted from the soil by the growing and harvesting of crops are phosphorus and potassium. In their pure state, both phosphorus and potassium are deadly poisons. And so it can be seen that neither of these elements could be used directly as plant food. They, like nitrogen, must exist in compounds that are soluble in water before they can become available as plant food. They are usable by the plant when they occur as chemical combinations in the form of nitrates, phos-

phates, and sulphates such as we used in Experiment 106.

IV. HOW SOIL IS KEPT FERTILE

When soils are cultivated and crops *are removed*, the plant-building compounds are taken from the soil. For



SOUTHERN COTTON FIELD

The fertilizer needed in greatest abundance for this crop is potash

every bushel of wheat harvested, it is estimated that more than a pound of nitrogen is taken from the soil.

So rapidly do the growing plants use up soluble com-

pounds of nitrogen that the nitrogen would soon be removed from most soils if it were not in some way replaced. Wheat crops rapidly exhaust soluble phosphorus compounds from the soil; and generous supplies of potassium compounds are necessary for the successful raising of cotton.

Fertilizers.—Substances that furnish elements needed for the life and growth of plants are called *fertilizers*. The most common fertilizers are manures. They contain nitrogen and potassium in about the proportions needed for the raising of ordinary crops, but they are not so rich in phosphorus.

Commercial fertilizers generally contain one or more of the three elements mentioned, in proportions adapted to the needs of varying crops.

Oral Report.—What are the sources of our most important commercial fertilizers—phosphate rock, potash, nitrates, bone meal, dried blood, etc.?

Various Kinds of Bacteria as Fertilizing Agents; Bacteria of Decay.—If a soil had all necessary substances for plant growth in it, it would still lack fertility if it were not for the microscopic life of the soil.



SOIL BACTERIA

We have learned that decay is caused by minute living things, called bacteria. These bacteria are one-celled plants. The soil teems with these low forms of life. It has been estimated that there are fifty thousand germs of various kinds in a gram of fertile soil. Certain

kinds of bacteria work the humus over and over, each kind doing a different work, until the proper nitrogen compounds are formed. When these are dissolved in

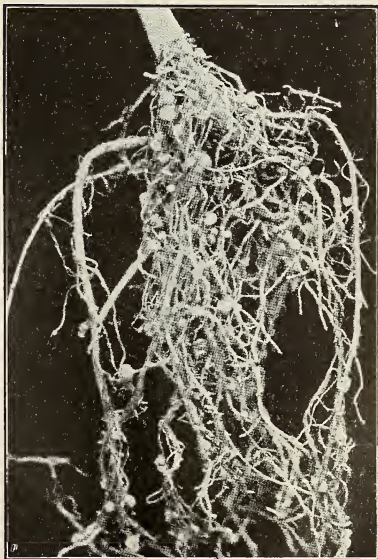
soil water, they are ready to be taken up for food by the plant.

The *bacteria of decay* do not add to the nitrogen of the soil; they simply work over the nitrogen compounds that they encounter. They actually feed upon the plant and animal refuse that is in the soil. Part of the organic substance serves the bacteria as food. The waste products thrown off by the bacteria are nitrogen compounds that the rooted plant can use.

Without the activities of these soil bacteria, the growing plant would die for want of properly prepared food.

Nitrogen - fixing Bacteria; Rotation of Crops.—Among the most important fertilizing agents are the *nitrogen-fixing bacteria*. These dif-

fer from the other kinds of soil bacteria mentioned, in that they are able to take nitrogen directly from the air between the soil particles and to combine it into compounds. Thus they *add* fertilizing compounds to the soil. Farmers know that if a field is sowed to clover or to soy-beans, for ex-



THE NODULES CONTAIN NITROGEN-FIXING BACTERIA

The roots of such plants as the clover, pea, and bean (*leguminous plants*) have these nodules.

ample, it becomes more fertile. This is owing to the fact that the nitrogen-fixing bacteria live and multiply in great numbers in knots, or *nodules*, on the roots of these plants. Under the right kind of conditions, the bacteria produce more nitrates than the growing plant can use, and the accumulation of nitrates enriches the soil. It is wonderful how these high and low forms of plant life, working together, serve each other, and by their combined service fertilize the soil.

Soil nitrifying bacteria are among the farmer's most efficient helpers. Commercial fertilizers are expensive, but here are millions of one-celled plants ready to fertilize the soil actually at a profit.

A wise farmer alternates or *rotates his crops*. This means that every year or two he lets his land "rest," in order to give nitrifying bacteria a chance to refertilize it. For example, after a wheat crop is harvested, a field may be sowed to clover. Before frost the clover has a good start. Early the next summer, such a field yields a crop of clover hay. A second crop grows during the summer, and this may yield seed or serve as pasturage for cattle. The roots and whatever is left of the second growing crop are plowed under to enrich the soil. Thus even while the soil is being refertilized for major crops of grain or cotton, it is rendering service to the farmer.

Most farmers divide their farms into fields and rotate the crops in these fields so as to have some portions of the farm producing major crops every year.

Oral Report.—What forms of animal life that live in the soil help to make it more porous and more fertile? A very simple and interesting story of how animals give tireless help in the farming of the land is told in "The Adventures of a Grain of Dust," Hallam Hawkesworth (Scribner's).

V. UNDERGROUND SUPPLY OF WATER AND AIR NECESSARY FOR PLANTS

Free Water in the Soil.—We have learned that each minute particle of soil has a film of water around it. The spaces between the soil particles are occupied either by air or by *free water*. Both are necessary for plant roots. After the plant roots have used up the film-water around soil particles (page 332), this film must be replaced.

Experiment 107.—Tie pieces of cloth over the ends of four lamp chimneys. Fill one of the chimneys with coarse sand, another with fine sand, another with clay, and the fourth with a deep black loam. Stand each chimney in a shallow pan of water. (Figure 111.) Allow them to remain for a week, keeping water in the pan all the time. Note how high the water has risen in the different chimneys at the end of an hour: two days: a week.

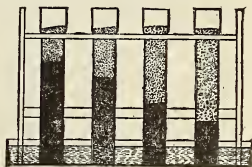


FIGURE 111

Experiment 107 shows how free water rises in the soil by capillarity just as it rose in the wick in Experiment 76. This free water rising from below replaces the films around the soil particles and thus keeps the plant roots supplied with moisture.

Plants need a great deal of water. It has been estimated that the cabbage crop on an acre of soil draws from the soil and transpires (page 171) a half million gallons of water in one summer. A corn crop to be successful needs eight inches of rain during the three months while it is coming to maturity. In order to absorb an ounce of plant-food from the soil, the ordinary plant must absorb a barrel of water.

But there is a limit to the action of capillarity. If the water-table (page 219) is very far below the surface of the

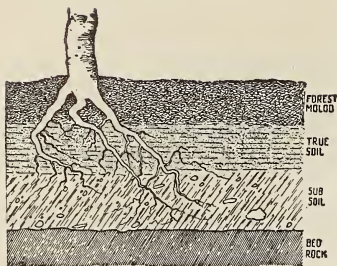


FIGURE 112

ground, the water will not return by capillarity to the surface. Sometimes during a dry season, the water-table is lowered so much that crops are parched and stunted for lack of water.

Some plants are able to extend broadly and to sink deeply (Figure 112).

A single oat plant has been found to have an entire root extension of over 150 feet. This seeking of the roots for water sometimes causes the roots of trees to grow into drain pipes and stop them up. For this reason the planting of certain trees near sewer pipes is often prohibited.

Certain trees and plants have such long roots that they can reach the underlying water and flourish where other plants will die. When wet lands are so drained by tiling that the plants can send their long roots down to this constant water supply or water-table they stand a drought much better than plants



ROOT SYSTEM OF ALFALFA

This picture shows how deep alfalfa roots go to seek water.

grown on undrained land where the water-table has not so uniform a depth. The too frequent surface watering of plants is bad for them, as it keeps their roots so near the surface that the plants are unable to withstand slight drought.

Soil Air.—**Experiment 108.**—(Teacher's Demonstration.)—Fill an 8-oz. bottle with soil taken from a few inches below the surface. Fit the bottle with a two-holed rubber stopper having the long neck of a three or four-inch funnel pushed as far as possible through one hole and a bent delivery tube just passing through the other hole. See that there is no air space between the soil and the stopper. The soil in the bottle should be as hard packed as it was originally in the ground. If necessary, push a wire down through the neck of the funnel so as to free all hard-packed particles of soil in it.

Connect the delivery tube with a bottle full of water standing inverted on the shelf of a pneumatic trough. Pour water into the funnel until it is full, and keep it full during the rest of the experiment. Allow the apparatus thus arranged (Figure 113) to stand for some hours. Air will collect in the bottle over the pneumatic trough. Where did it come from? When the soil in the bottle has become entirely saturated with water, roughly compare the amount of air collected with the volume of the bottle containing the soil. What part of this soil's volume is the collected air?

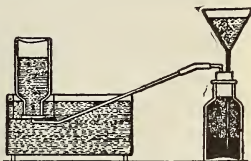
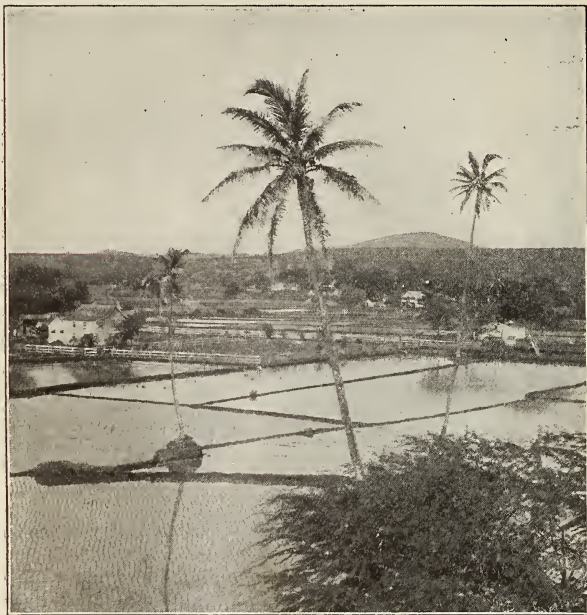


FIGURE 113

Experiment 109.—(Teacher's Demonstration.)—Boil some water so as to drive out the air and after it has become cool fill a 2-quart fruit jar half full. Dissolve in this all the necessary plant food as was done in Experiment 106, making the solution the same strength. Place in this a slip of Wandering Jew. Pour over the surface of the water a layer of castor oil or sweet oil. Place this jar alongside the slip in the other complete food solution, Experiment 106. Both slips have the same conditions except that the oil keeps out the air from the roots of one of them. Does the absence of air effect the growth of the slip?

We have seen by Experiment 108 that the soil contains air as well as water. Experiment 109 shows that if plants

are to thrive, their roots must have air. If the ordinary potted plant has its roots submerged in water, the plant very soon turns yellow. For the same reason, crops do



RICE SWAMP

Rice roots must be kept submerged. The roots obtain the air they need from air dissolved in the water.

not thrive in areas where the soil is saturated to the surface with free water.

None of the helpful bacteria can work without a supply of soil air. It is necessary, too, that the air be changed frequently. The soil must be ventilated. This is one of the reasons for keeping the soil mellow by plowing or

hoeing. Another reason is that the tips of roots are delicate and if they are to grow readily, they must have mellow soil through which to find way. These reasons for tillage are quite as important as the killing of weeds which would use the space and plant foods needed by the growing crops.

Too much free water excludes the air from the ground and the plant literally drowns. This is what causes orchards on undrained mountain ledges to die of "cold feet." Even where there is not sufficient free water to drown the plant, insufficient under-drainage keeps the soil cold and prevents the surplus of acid wastes thrown off by soil bacteria from being washed out of the soil.



ALKALI SOIL

Few plants can grow here because of the excess of alkaline salts.

This explains why flowerpots always have drainage-holes and why farmers are sometimes compelled to tile their farms.

Certain kinds of plants need more water than others. They thrive if they are submerged in it, or even if their roots are submerged. Water lilies, reeds, rice, and other plants grow with their roots submerged in water. The

roots of such plants obtain their needed air, as do fish, from the air dissolved in the water (page 226). Other plants, such as the cactus, sagebrush, and mesquite, can grow only where the supply of moisture is very scant.

VI. FARMING IN RAINLESS REGIONS

Reclaiming Alkali Land by Irrigation.—Experiment 110.—(Teacher's Demonstration.)—In a fruit jar make a very strong solution of potassium nitrate or, as it is commonly called, saltpeter. Place in this a slip of Wandering Jew. Does the slip grow well?



IRRIGATION IN SQUARES

It has a great abundance of nitrogen, which was found so important. Place in a similar strong solution a growing beet or radish freshly removed from the ground. Notice how it shrivels up. Place a similar beet or radish in water. Is it similarly affected? What is the effect of strong solutions on plants?

Here the osmotic action illustrated in Experiments 103 and 104 is reversed. The denser solution is outside the plant and so the less dense cell-sap passes out of the plant roots more readily than the denser solution in the fruit

jar enters the cells. The result is that the plant tissues wither. This explains why salt thrown on grass withers it.

In dry regions where rain sinks into the ground and after remaining for a time rises to the surface and is evaporated, large areas are found upon which almost nothing can be made to grow even when sufficient water is provided. Often in the dry season white or brown crusts appear scattered over the surface in large patches.



IRRIGATION IN FURROWS

The white crust usually tastes like Epsom salts and the brown like sal soda. The salts forming these patches have been dissolved out of the soil by the soil water and left on the surface when it evaporated.

The alkali salts are so readily soluble that the soil water becomes a solution stronger than the cell-sap of plants.

Such accumulations of salts are not found at the surface of the soil in wet regions because they are carried away by the water which runs into the streams. About the

only way soil of this kind can be treated to make it productive is to irrigate and drain it, thus washing the salts out of the soil. This is just what is done by nature in well-watered regions. Sometimes if *there is not much alkali*, deep plowing or the planting and removal of certain



EAST END OF THE ASSUAN DAM ACROSS THE NILE

The greatest irrigation dam in the world.

plants such as sugar beets, which are capable of growing in such soils, will remove the excess of alkaline salts.

In the last few years the government and many private companies have spent millions of dollars in putting in irrigation plants. By this means thousands of acres of land

which would otherwise have been valueless for agriculture have been made exceedingly productive.

Mulching to Prevent Loss of Soil Moisture.—Evaporation is the cause of soils losing the greatest amount of water. Soil water is constantly moving toward the surface on account of capillary action, and is being evaporated. This loss by evaporation must be counteracted, if in arid countries or during dry spells agricultural plants are to be provided with sufficient moisture.

Experiment 111.—Fill full of soil four tin cans having small holes punched in the sides and bottom. Water each with the same amount of water. Cover the first with about an inch of grass and the second with about an inch of sawdust, and weigh carefully. Weigh the third and fourth. Record the weight of each. Thoroughly stir the surface of the third, as soon as it is dry enough, about an inch deep. Keep this stirred. Let the fourth stand undisturbed. Weigh all four every school day for two weeks. Keep a record of the loss of weight of each. Why have they lost weight? How do the grass, the sawdust, and stirring of the earth affect the loss? Suggest ways to keep soils from losing their moisture.

In Experiment 111, it was seen that if a layer of grass or sawdust was put on the top of the soil, the moisture did not evaporate so rapidly as it did when the soil was not covered. The grass could have been replaced by shavings, manure, or any substance which would protect the ground from the sun and wind. Protections of this kind are called *mulches*. They are most frequently used around trees, vines, and shrubs. It is impracticable to use them extensively on growing crops.

It was also found that soil water was not readily evaporated where the top of the soil was kept stirred, so that the little capillary tubes by which the soil water reaches the surface were broken and the sunshine and air were kept

from the under part of the soil by a layer of finely divided soil mulch. And so the soil moisture is retained in the under layer ready for the plant roots.

Dry Farming.—In some parts of the arid region of the United States *dry farming* is practiced. The soil is deeply



KAFFIR CORN

A plant suitable for dry farming.

plowed and the plow often followed by a bevel wheel roller called a *soil packer*, in order to pack the under soil or sub-soil so that the air cannot circulate through it so readily and dry out the upper soil. The surface soil is then most thoroughly cultivated so as to make as perfect a soil mulch as possible. Thus, whatever moisture falls is kept from seeping below the reach of the plant roots and from evaporating from the surface. In this kind of farming the aim is to use more than one year's moisture in growing a crop.

Crops are usually planted only every other

year, two years' moisture being retained for one crop. The soil is, however, kept thoroughly cultivated all the time. Of course plants requiring the least amount of moisture are best adapted to dry farming.

Value of Soils.—Silt is the soil of the western prairies and the great grain-producing states of our country. It holds water well, contains an abundance of plant food, and is easily cultivated.

Different soils are adapted to different crops. Where a soil, although not good for many crops, is adapted for raising a crop which in its locality is valuable, the soil is called good. Thus the soil in many parts of Florida, although unsuited for raising most crops, is suited for orange trees and early vegetables, and so is a good soil. The stony soil in certain of the orange regions of California would be an exceedingly poor soil for most crops, but it is good for oranges and therefore it is most valuable.

In sandy soils, since there is usually little humus, the water soon drains out and plants become parched. Such soils warm up quickly in the spring and dry out rapidly after long wet spells. When humus and plant food in the form of manure are added, these soils are especially adapted for growing early crops and crops that do not require a great deal of moisture, such as grapes. The "Fresno Sand" of California and the sandy coast plains of the eastern United States are soils of this kind.

SUMMARY

The soil, which ages and ages of weathering and decay have produced, is the growing place of most plants and the home of many animals. The soil furnishes home, food, and drink to the higher forms of plant life. The best agricultural soil is composed of a mixture of sand, silt, and clay, with some decaying vegetable or animal matter in it. A naturally fertile soil is the product of ages of plant life and decay.

Each particle of soil has a film of water around it. Substances dissolved in this water-film serve as food for the plant. The plant takes up this water-film by osmosis.

The water taken into the plant root passes on from cell to cell by osmosis and by capillarity to the stem and leaves.

Nitrogen, phosphorus, and potassium are the soil elements that are used most freely by the growing plant. But they must exist in soluble compounds before they can become available as plant food. Nitrates, phosphates, and sulphates are fertilizing compounds. They are all of animal or vegetable origin. The bacteria of decay make animal or plant refuse available as plant food. Other bacteria which live and multiply in nodules on the roots of leguminous plants are able to take nitrogen from the air and work it into chemical compounds that fertilize the soil.

As the water-film around soil particles is taken up by plants, its place must be taken by more water which rises by capillarity from the water-table. In dry seasons when the water table falls too low, crops perish. Soil air is also necessary for plants. For this reason most crops do not thrive in soil that is saturated with free water. Ventilation of the soil is one of the reasons for keeping the soil mellow by plowing or hoeing. Certain kinds of plants thrive if their roots are submerged in water. Such plants obtain the air they need from the air dissolved in water.

Alkali lands are found only in dry regions. The alkali salts are dissolved and brought to the surface. Evaporation of the moisture leaves these salts at the surface. Through the centuries they have accumulated, until the surface soil is unfit for agriculture. Such soils can usually be reclaimed only by drainage and by irrigation.

In dry regions where irrigation is not possible, gardening and vine and tree culture are made possible by mulches. Dry farming is practiced in some sections by mulching the soil and conserving the moisture of more than one year for a crop.

Many soils that would be of little use for large agricultural crops are exceedingly valuable for citrus crops, grapes or early vegetables.

QUESTIONS

- How do soils differ in composition?
- What is the best mixture of soils for general farm purposes?
- How has nature prepared fertile soil?
- Of what service to plants is the water-film around soil particles?
- How do plants obtain this moisture?
- What are the three soil elements most needed by plants for food?
- What fertilizers furnish these necessary elements?
- What service do the bacteria of decay render to plants?
- What crops do farmers plant to enrich the soil? In what way do such crops make the soil fertile? What is meant by rotation of crops?
- Why is an underground supply of free water necessary for plant life?
- Why is swampy soil unfit for the raising of most kinds of crops?
- How do rice roots get their necessary supply of air?
- What is alkali land? In what ways may it be reclaimed?
- What is mulching? What is its purpose?
- How is dry farming carried on?
- Stony and sandy soils usually lack fertility. Why are many stony or sandy areas in Florida and California so valuable?

CHAPTER XIV

LIGHT AND ITS RELATION TO LIFE

*Flowers, leaves, fruit, are therefore air-woven
children of light.*—Moleschott.

The Importance of Light.—Light is another form of energy. Some of the ways in which it acts and many of the things it does are known to us. That light is related to other forms of energy has been proved, but the real nature of light is still a riddle to man.

We have not learned to exercise control over the energy of light in as many different ways as we have over the energy of heat. But in the last quarter of a century we have made great progress in acquiring knowledge of the properties and uses of light.

The most important thing we know about light is that life is absolutely dependent on it. Man knows no possible way of manufacturing the lifeless substances of the soil and air into food. He may prepare food so that it is more inviting and easier to digest, but he is dependent on the growing plant for raw food materials. Plants are the only food factories in the world, and light is the form of energy that runs these factories.

We know that heat energy is necessary to plant life and growth but this form of energy alone is not sufficient. A thrifty plant may have fertile soil and ideal conditions of heat, moisture, and air; yet if it be deprived of light it will sicken and die for lack of properly prepared food. If it were possible for the earth to have all the heat necessary for life, but no light, we should eventually starve to

death. Light, therefore, must be added to heat, water, and air as a prime essential of life.

We have seen that the source of all our light is the sun. We may safely say *all* our light, because the stars are so far away that their pale gleams could be of no service to us in maintaining life.

Even our artificial lights have had their origin in sunlight. The wood, the coal, the fats, the oils, the gases we burn may all be traced back to living things. The energy of falling water is simply transformed sun-energy (page 75). The electric current which lights our homes and streets is a transformation of sun-born energy. And so the light of the sun is the parent of all artificial lights.

The development of artificial lighting has had tremendous bearing on extending man's activities and increasing his efficiency.

Light makes possible our power of vision, and man is dependent on his sense of sight for a greater number of activities than upon any other sense. His dominion over the beasts of the field is by virtue of his intelligence, and this intelligence is exercised largely through his sense of sight. His progress depends on discovery and invention; and these in turn are largely products of vision.

I. LIGHT AND LIFE

Carbon Needed by the Growing Plant.—Experiment 112.—(Teacher's Demonstration.)—Boil a few fresh bean or geranium leaves for a few minutes in a beaker of water. Pour off the water and pour on enough alcohol to cover the leaves. Warm the alcohol by putting the beaker in a dish of hot water. When the leaves have become colorless, remove them from the alcohol and wash them. Place the leaves in another beaker and pour on a solution of iodine. (This solution can be made by dissolving in 500 ccm. of water 2 grams of potassium iodide and $\frac{1}{2}$ gram of iodine. After using it here, it should be bottled and kept for Experiment 134.) If the leaves turn dark blue or blackish, starch is present.

Experiment 113.—Place a little starch in a test tube and heat it

over a flame. As you heat the starch, a gas is driven off, water collects near the mouth of the test tube, and a black substance remains in the test tube.

The black substance left in the test tube in Experiment 113 is carbon. The water which collected at the mouth of the test tube shows that starch also contains hydrogen and oxygen. (Page 90.) Starch is a plant product; it is a compound of carbon, hydrogen, and oxygen. Compounds, such as starch and sugar, in which there are only carbon, hydrogen, and oxygen, form a large part of the make-up of all plants. Such compounds are called *carbohydrates*.

We have seen that the root-hairs absorb water from the soil and take in with it certain dissolved soil elements. But carbon is not among the elements listed in Chapter XIII as being necessary to the fertility of soil. Many experiments have proved that a soil containing carbon is neither more nor less fertile by reason of the presence of the carbon. On the other hand, it has been proved that if a growing plant is confined to air from which all carbon dioxide has been removed, it will die.

Soil water furnishes the hydrogen and some of the oxygen for the carbohydrates in the plant make-up, but we are forced to conclude that the plant must obtain its supply of carbon from the atmosphere.

What gas in the atmosphere contains carbon?

How the Plant Obtains Its Necessary Carbon.—If the green plant is dependent for food upon a gas in the atmosphere, it must have some way of taking in this gas and of expelling gases that are of no use to it. This process corresponds to breathing in man, but it is not effected in the same way. In both plants and animals, it is called *respiration*.

To understand how respiration goes on in the green plant, we must understand something of the structure of a leaf. Covering the whole leaf is a thin, transparent,

tissue-like skin or *epidermis*. This epidermis may be readily peeled from some leaves, but from others it is too delicate to be removed except with great skill.

Under a microscope, a bit of leaf epidermis looks somewhat like a brick wall. The closely joined rectangular bodies (Figure 114) are cells containing protoplasm, the living substance of the plant. The microscope reveals among these brick-shaped cells pairs of crescent-shaped cells which guard little openings through the epidermis. Such an opening is called a *stoma* (plural, *stomata*), from the Greek word meaning mouth. Each leaf has thousands of stomata, most of which are on the under side, away from the sun's rays.

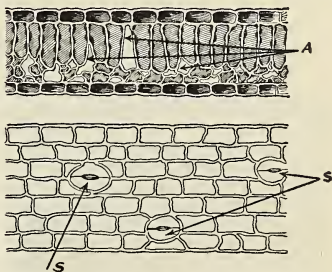


FIGURE 114.—CROSS SECTION OF LOWER EPIDERMIS OF A LEAF

Greatly magnified to show cells. A, air spaces between cells; S, stomata in leaf epidermis.

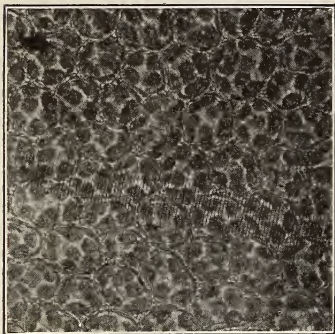
Between the upper and lower epidermis of the leaf lie two more rows of cells. Air spaces in the under row make it possible for the air which enters the stomata on the under side of the leaf to reach all the cells.

Water and Carbon Dioxide Meet in the Leaf Cells.—
Experiment 114.—Place the freshly cut stem of a white rose, white carnation, variegated geranium leaf, or any thrifty leaf which is somewhat transparent, in a beaker containing slightly warmed water strongly colored with eosin. Allow it to remain for some time. The coloring matter can be seen to have passed up the stem and spread through the leaf or flower.

The veins of the leaf serve to convey water to the cells, which pass it on to each other by osmosis. Thus

we see that the water taken up from the soil and the carbon dioxide taken in from the air meet in the leaf cells.

Leaves as Food Factories.—The great function of the leaf is to manufacture plant foods. In the two inner layers of cells protected by the leaf epidermis is a green substance called *chlorophyll*. This has the power to utilize



CHLOROPHYLL BODIES OF A LEAF

Note the separate cells. Each cell contains about a half-dozen chlorophyll bodies.

the energy of sunlight to combine the carbon, hydrogen, and some of the oxygen of carbon dioxide and water into new compounds that contain all three elements. The changes that occur are rapid, numerous, and complicated. Scientists do not fully understand how these rapid changes are effected by light in the presence of chlorophyll, but they recog-

nize the final products as sugar or starch.

This manufacture of carbohydrates may go on in any *green* part of the plant—that is, wherever there is chlorophyll. But the amount of chlorophyll in the stem and elsewhere is comparatively small, and so the main work goes on in the leaves.

The cells in the leaf and in other parts of the plant have the power to change the sugar and combine it with other substances contained in the sap, thus forming more complex chemical compounds. These contain nitrogen and sulphur, besides the elements of the sugar. Such com-

pounds are called *proteins*. They are essential to the formation of plant protoplasm and are very important as animal foods.

The plant cells may also change sugar or starch into oils. The oils are also carbohydrates and are usually stored in the seeds of plants. Olive oil, corn oil, linseed oil, and cotton seed oil are among the most useful oil products that the plant factories furnish to man.

How Leaves Adapt Themselves to Their Supply or Light.—The plant factories must have an adequate supply of light energy. If we examine the arrangement of the leaves on a plant or tree, we shall see that they do not lie one directly above the other, but that they are arranged so as not to shade one another. Their position generally is such that the broad upper surface of the leaf receives the strong light rays perpendicularly upon it. To accomplish this, the leaves in many trees are arranged spirally around the stem.



DIFFERENT FORMS WHICH LEAVES ASSUME

The stem of the leaf itself, in some parts of the tree, often grows long and twists about, in order to push the leaf out to the light and yet not let it be wrenched away by the wind. The horse-chestnut has such a leaf. In some plants, like the sunflower, the younger leaves follow the sun all day. For other plants the rays of the sun seem to be too bright in the middle of the day



A SUNFLOWER PLANT

and so the leaves of such plants are held edgewise to the midday sun.

A striking example of this is the compass plant, the leaves of which arrange themselves so that the sun's rays strike the broad surface of the leaves in the evening and morning when the rays are not very strong, but at noon the edge of the leaf is toward the sun, the leaf thus maintaining a nearly vertical position all day, with its greatest

length extending in a nearly north and south line. It is the effort to regulate the amount of light falling on the leaf, and not any magnetic influence, which causes the leaf to point in the direction of the compass needle.

How Leaves Adapt Themselves to the Supply of Moisture.—Experiment 115.—(Teacher's Demonstration.)—Procure a small, thrifty plant growing in a flower-pot. Water the soil and allow it to drain. Take two straight-edged pieces of cardboard sufficiently large to cover the top of the flower-pot and notch the centers of the edges so that they can be slipped over the stem of the plant and thus entirely cover the top of the



FIGURE 115

Adaptation of Leaves to Moisture Supply 361

flower-pot. Fasten the edges of the cardboard together by pasting on a strip of paper. The top of the pot will now be entirely covered by the cardboard but the stem of the plant will extend up through the notches of the edges. Cover the plant with a bell jar. (Figure 115.) Very little moisture can get into the bell jar from the soil in the pot, as it is closely covered. Set the plant thus arranged in a warm, sunny place. Moisture will collect on the inside of the bell jar. This must have been given out by the plant leaves.

The water which the plant does not use in the manufacture or transportation of food is thrown off by the leaves, as seen in Experiment 115. This, as we have learned, is called transpiration. It aids, just as perspiration does in man, to keep the living organism at the right temperature. It has been shown (page 341) that the amount of water thus thrown off by plants is very great. A single sunflower plant about six feet tall gives from its leaves about a quart of water in a day, and an acre of lawn in dry, hot weather gives off probably six tons of water every twenty-four hours.



EUCALYPTUS LEAVES

If the water passes out of a plant too rapidly so that there is not enough left to provide for the making and transporting of the food, the work of the plant cannot be carried on, and the plant dies. It is on account of this that many plants are especially prepared to retain their water supply. In almost all plants the *stomata*, or little

pores in the leaf through which the water passes out, close up when too much water is being lost.

In some plants, like the corn, when the root cannot supply sufficient moisture, the leaves curl up and thus present less surface for evaporation. In trees like the eucalyptus the leaves hang vertically when the sun gets too bright and present their edges to the sun's rays. Some



CACTI

These are adapted to desert life because they have no leaves from which water can evaporate.

leaves, like the sage, are especially prepared to conserve their moisture by having their surfaces covered with hairs. Others have a waxy covering, as the cabbage and the rubber tree. In some plants the leaves are very small and have few pores, as the greasewood of the desert, and some have done away with leaves altogether, as the cactus. It is because the roots can not supply sufficient moisture where the ground freezes in the winter that trees having

large leaves shed them. Only trees like the pine, whose needlelike, waxy leaves give off almost no moisture, can retain their leaves.

The Plant Lives at Night off the Products of the Day.—

Experiment 116.—Place a thrifty geranium or other green plant in darkness for two or three days and then treat the leaves as was done in Experiment 112. Do they show the presence of starch? The direct presence of the sun's energy in the form of light is necessary for the formation of starch in the leaves.

It was found in Experiment 112 that leaves exposed to the sun contained starch, and in Experiment 116 that leaves which had been deprived of sunlight did not have starch. The starch disappeared while the plant was in darkness.

The starch manufactured is insoluble in water and is stored in the leaf during the day. But at night, when the leaf is not manufacturing starch, it is able to digest the starch by means of a special substance, *leaf diastase*, which it forms. This changes the starch into sugar, which is soluble and which is carried in solution to other parts of the plant. If the plant is kept too long in the dark, it uses up all the foods it has prepared, and dies for want of food which can be produced only by the aid of light energy.

The digested and soluble substances which are prepared by the leaves may be used directly as food to supply energy for the work of the growing plant. Oxygen is used by the plant in releasing this stored-up energy. In other words, the carbohydrates are oxidized (page 356), thus releasing heat energy for the use of the plant. If the carbohydrates are not used directly as food for the plant, they may be changed in the leaf into proteins or oils, or transported to other parts of the plant, where they are combined with other substances contained in the cell sap.

Thus the plant is able to increase its protoplasm and to form new working cells as well as other substances, such as woody cells, oils and resins.

How Plants and Animals Serve Each Other.—Experiment 117.—Under an inverted funnel in a battery jar, place some pond scum or hornwort. Fill the jar with fresh water and over the neck of the funnel place an inverted test tube filled with water. (Figure 116.) When placed in the sunlight, bubbles of oxygen will rise into the test tube and collect. The oxygen can be tested by turning the test tube right side up and quickly inserting a glowing splinter. If the splinter bursts into a flame, oxygen is present. (A freshly picked leaf covered with water and put in the sunlight will be seen to give off these bubbles.) After a small amount of gas has been collected in the test tube, mark the height of the water column and place the battery jar in the dark, allowing it to remain there for ten or twelve hours. No oxygen is given off in the dark. Place the jar in the light again. Oxygen is given off.

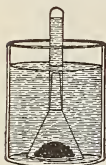


FIGURE 116

Not all of the oxygen from the carbon dioxide and the water is used in the manufacture of starch by the chlorophyll, and so some of the oxygen becomes a waste product which the leaves throw off.

When the chlorophyll is without light energy to enable it to manufacture carbohydrates, there is no surplus of oxygen. In fact oxygen is being used to oxidize carbohydrates and to release stored-up energy for the life of the plant.

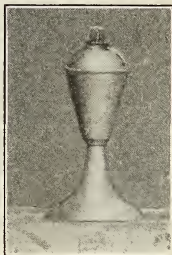
We have seen that animal wastes furnish food for plants, and plants furnish food for animals. Experiment 117 illustrates another way in which they serve each other. When animals breathe the air, they use oxygen to oxidize foods in their bodies to furnish them energy. The waste product which animals breathe back into the air is carbon dioxide. This very carbon dioxide is, as we have learned, necessary to the life of green plants. They, in turn,

release oxygen from the carbon dioxide and return the surplus to the air for the use of animals.

Voluntary Class Project.—To make and study a balanced aquarium.—In an aquarium that contains no plant life, the water must be changed frequently to supply oxygen for the water animals. Why is it not necessary to change the water in a balanced aquarium? From what source do the plants obtain their carbon dioxide? From what source do the animals obtain their oxygen? From what source do the animals obtain their food? What purpose do the nitrogenous wastes of the animals serve? Why is this called a “balanced” aquarium? What do you think is meant by the expression “balance of life” in all nature?

II. THE DEVELOPMENT OF ARTIFICIAL LIGHT

Primitive Lighting.—The discovery and control of fire gave man his first artificial light. The earliest caves occupied by primitive man show evidences of his use of fire for warmth and lighting. After centuries and centuries of bonfire lighting, some one discovered that a wick of dried moss in a bowl of liquid animal or plant fat would give a steadier and more enduring light. Then followed the use of solid fats with moss wicks; and finally the invention of the candle, which for centuries was the ideal artificial light.



AN OLD WHALE-OIL
LAMP

Candles and Whale-oil Lamps.—Assignment.—Review Unit IV of Chapter V, and Experiment 76 on Capillarity: and explain how a candle gives light.

We have seen that a candle does not burn in its solid or in its liquid form but only when its molecules diffuse in the form of a gas or vapor. If the candle you study is of paraffin, a product distilled from petroleum, its vaporizing point is very high as compared with the boiling point of

water. At ordinary atmospheric temperatures it remains a solid. The heat of the flame melts enough of the paraffin near the wick to form a bowl and to keep it filled with a liquid supply.

Up to seventy-five years ago, candles and whale-oil lamps furnished the best artificial lights obtainable. The whale-oil lamp gave a smoky light that could hardly be



Courtesy Chicago Tribune

SPECIAL ILLUMINATION IN 1869

This shows the Chicago Tribune Building illuminated in honor of the completion of the Pacific Railway. Compare this with the picture of the Wrigley Building on page 369.

called superior to that of the candle. But about the middle of the nineteenth century, whale oil became scarce, and efforts were made to provide other illuminating oils.

Petroleum.—In 1846 a satisfactory lighting oil was distilled from coal. This was called *coal-oil*. A short

time afterward, a method was devised for obtaining *kerosene* from crude petroleum. The two products were confused in the minds of many people, with the result that the name coal-oil still survives in many sections as a synonym of kerosene. The new method of producing kerosene, combined with the discovery of petroleum in abundance, made kerosene the important means of lighting for several decades.

Petroleum is a mixture of many oils, each of which has a different boiling point. It is this difference in boiling points that enables refineries to separate the oils from each other. The crude oil is raised to various stages of temperature; and at each stage a different kind of oil is vaporized, is carried away and condensed (page 313).

Gasoline and Kerosene.—Experiment 118.—(Teacher's Demonstration.)—Provide two small metal dishes or baking-powder can covers, two large asbestos mats, a tuft of cotton, and a heavy piece of glass to use as a slide cover.

Place a metal dish in the center of each asbestos mat. Pour over the bottom of one dish a film of gasoline. (Caution: be sure that the gasoline container is closed tight and removed to a safe distance, if not from the room, before proceeding.) Stand well away from the metal dish and hold a long lighted taper close to the surface of the gasoline film. Does it flash or take fire readily? Extinguish the flame with the glass slide and remove the dish to another part of the room.

Now pour about five cc. of kerosene in the other metal dish and try to light it with a taper. Does it flash or take fire? Place in the kerosene a tuft of cotton. As soon as the cotton is saturated, light it. Does the oil now take fire and burn steadily without wholly consuming the cotton?

Vapor is always rising from the surface of any liquid; but the higher the boiling point of the liquid, the less vapor there is forming at ordinary room temperatures. The boiling point of gasoline is so low that it gives off, at ordinary room temperatures, enough vapor to flash when a taper is applied to it.

Why do gasoline filling-stations have rules to prevent the filling of automobile gas tanks while the engine is running or occupants of the car are smoking? Why is gasoline for a gasoline stove kept in an airtight tank at a distance from the flame?

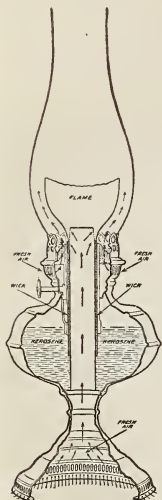


FIGURE 117.—DIAGRAM OF A KER-
OSENE LAMP

The boiling point of kerosene is so much higher than that of gasoline that it does not give off enough vapor at ordinary room temperatures to flash or to take fire. If you had raised the temperature of the kerosene by putting it over a Bunsen burner flame, you could have lighted the rising gas with a taper. But with kerosene at the temperature of the room, it was necessary to provide some way of vaporizing it more rapidly.

By capillary attraction, kerosene rose in the cotton. When the cotton was lighted, the kerosene was vaporized rapidly enough to provide steady fuel for the fire. As fast as the kerosene evaporated and burned, capillary attraction kept the liquid rising in the cotton.

Assignment.—Study the accompanying diagram (Figure 117) of a kerosene lamp and explain how it operates. It is difficult to realize how much the glass chimney added to the efficiency of lighting. It not only steadied the blaze from strong air currents, but provided a way of controlling the air supply from below and thus of making a clear flame (page 97). Why does the kerosene lamp smoke if the wick is turned too high?

Illuminating gas was produced and used for lighting purposes in a very



GAS MANTLE

limited way in England over a hundred years ago, but it did not come into popular use until the last quarter of the nineteenth century. It provided a cheaper, safer, and more convenient way of lighting homes, factories, and streets. But so far as efficiency of lighting was concerned,



Courtesy Morton Salt Company

NIGHTLY ILLUMINATION IN 1924

The contrast between this picture and the picture of the Tribune Building in 1869 shows better than words can tell the progress in artificial lighting that has been made in the last half century.

it offered little advantage over kerosene until about 1885, when Carl Auer von Welsbach, a German, made practical the gas mantle.

He discovered that if a piece of cotton fabric be saturated with the salts of two rare metals (cerium and thorium) the cotton burns, but the ash retains the form of the fabric. Moreover, the ash glows brilliantly in the flame of a Bunsen burner. This discovery gave him the idea

for the device now called the Welsbach mantle, which produces a more brilliant flame with a smaller consumption of gas.

In later years, electric illumination has been rapidly displacing all other forms of lighting. This we shall discuss in a later chapter.

It is difficult for us to appreciate how numerous are the advantages and how much greater the power of illumination when kerosene, gasoline, acetylene, illuminating gas, and electricity are used. In many sections of our large cities artificial lighting almost turns night into day. So enormous is the amount of fuel used for the brilliant lighting of our cities that the United States Government was compelled to combine "lightless nights" with "daylight saving" in the interest of fuel economy during the World War.

III. LIGHT IN THE HOME

Direction of Light Movement.—Experiment 119.—Point the pin-hole end of a camera obscura or pin-hole camera (this consists of two telescoping boxes, the smaller having a pin-hole at the end and the larger a ground glass plate, (Figure 118) at some object and move the ground glass plate back and forth until a sharp image of the object is formed. Sketch on a piece of paper the object and the image, showing the direction in which you think the rays of light must have traveled through the pin-hole to form the image.

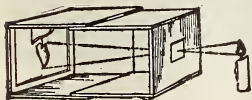


FIGURE 118.—PIN-HOLE CAMERA

If we wish to see whether the edge of a board is straight, we sight along it. If we wish to hit an object with a bullet, we bring the rifle barrel into our line of sight. We therefore feel confident that if light is traveling through a uniform medium, such as air usually is, it goes in a straight line.

Why Objects Are Visible.—We cannot see objects in the

dark, but if a light is brought into the room so that it can shine upon them, they become visible. We see them because the light is reflected to us from them. All objects except self-luminous bodies are seen by reflected light. Most of the bodies that we know are dark and non-luminous. Sometimes some of these which have polished surfaces reflect the light from a luminous body and thus appear themselves to be furnishing light.

An example of this is often seen about sundown when the sunlight is reflected from the windows of a house, making them look as if there were a source of light behind them. Any dark body whose surface reflects light appears itself to be luminous as long as the source of light remains, but grows dark again when the source is removed. This is the case of the moon. At new moon, the moon is so situated with respect to the sun that light is not reflected to the earth and we cannot see it. At full moon, half of the moon's entire surface reflects the sunlight, and it appears very bright.

If a lighted candle is held in front of a mirror and we look into the mirror, we see the candle behind it. We know that the candle is not there but that its light is reflected by the mirror in such a way as to make it appear to come from behind the mirror. We see the candle by the light the mirror reflects.

On a cloudy day we cannot see the disk of the sun at all and yet we have light. On such days the light comes to us wholly by reflection. The rays of light from the sun are reflected innumerable times from particle to particle of moisture and dust until the much-reflected light finally reaches our eyes.

The Intensity of Light.—Experiment 120.—(Teacher's Demonstration.)—Take two square pieces of paraffin about an inch thick, or better two squares of parowax, and place back to back with a piece of cardboard or tinfoil between them. When a light is placed on

either side of this apparatus the wax toward the light will be illuminated, but not that on the other side of the cardboard. (Figure 119) If lights are placed on each side, it is easy to see when both pieces of

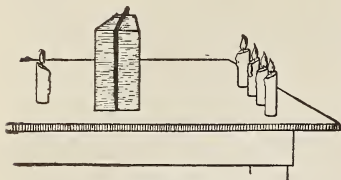


FIGURE 119

wax are equally illuminated, or receive the same amount of light. In this way the strengths of lights can be compared.

Place a candle about 25 cm. in front of one side of this apparatus, and 4 candles, placed close together on a piece of cardboard so that

they can be readily moved, about 90 cm. away on the other side. Move these candles back and forth till a position is found where both pieces of wax are illuminated alike. Measure the distance of the four candles from the wax. How many times as far away are they as the one candle?

The standard measure for intensities of light is the candle power. This is the light given out by a standard candle, which is practically our ordinary No. 12 paraffin candle. A 40-watt Mazda incandescent electric light is 40 candle power. (No understandable figures will express the intensity of the sun, using the candle power as a measure.)

Figure 120 illustrates a definite measure of illumination which lighting experts use. It takes into consideration both candle power and distance. The light cast by one candle on one square foot of surface one foot away is called a *foot-candle* of illumination. At a distance of 2 feet, the same rays of light illuminate a surface of 2×2 ,

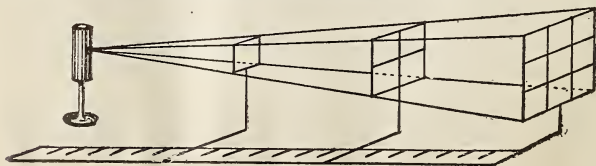


FIGURE 120

or 4 square feet. And so each square foot of surface receives only one-fourth of a foot-candle of light. At a distance of 3 feet, the same rays illuminate 3×3 , or 9 square feet of surface. Each square foot of surface, therefore, receives only one-ninth of a foot-candle of illumination.

This rapid decrease in the brightness of light as the distance increases is the reason why so small a change in the distance of a lamp makes so great a difference in the ease with which we can read a book.

The intensity of light, like that of heat and electricity, and all forms of energy which spread out uniformly from their point of origin, varies inversely as the square of the distance from the source. If we make the distance to the lamp half as great, we increase the amount of light on the book four times; if one-third as great, nine times; if one-fourth as great, sixteen times; etc.

Amount of Light Necessary for a Study-Table.—A sufficient amount of illumination for studying at a table or desk may be had from the light of five candles at a distance of one foot—five foot-candles. If the same illumination is to be had from a lamp two feet away, a twenty candle power light will be required ($2 \times 2 \times 5$). To get equal illumination from a distance of three feet, a forty-five candle power light will be needed ($3 \times 3 \times 5$).

Protect the Eyes by Avoiding Glare.—If we look at the sun for an instant, or at a bright spotlight in the dark, we realize that the eyes must be protected from lights of too great intensity. But we often fail to realize that we may suffer from the glare of much less intense lights. If we sit facing the window all day while we work at our desks, or if we have our lamps so placed that the light may strike our eyes directly, even though we may not be aware of

it, we are putting a strain on our eyes that may lead to trouble.

Even light reflected from too bright a surface may be injurious. Reading a book in the glare of sunlight or studying close under a very powerful light is harmful to the eyes. Modern offices are getting away from the use of desk lamps. All lighting is being done by powerful lamps close to the ceiling.

Voluntary Project.—To determine whether an electric study light is of about the right intensity.—All incandescent electric lights are rated and labeled in watts according to the amount of current they consume. In carbon filament lamps, you may estimate roughly that every four watts is equivalent to one candle of illumination. A 40-watt carbon filament lamp, for example, would be a 10-candle power lamp ($40 \div 4 = 10$). Mazda lamps are much brighter. In these, you may roughly estimate the candle power as being equal to the number of watts. A 40-watt Mazda lamp would, therefore, be a 40 candle power lamp.

At a distance of one foot from your printed page, a 40-watt Mazda lamp would furnish 40 foot-candles of illumination. At a distance of two feet, it would furnish 10 foot-candles of illumination ($40 \div 2^2$). At a distance of three feet, it would furnish between 4 and 5 foot-candles of illumination ($40 \div 3^2$). In other words, divide the candle power of the lamp by the square of the distance from your book to find the foot-candles of illumination on your study page.

Report on whether you have been using about the right intensity of illumination. If you have been using too little or too much, tell what you can do to remedy the condition.

Light May Be Absorbed, Reflected, or Transmitted.—There is no glass nor any other substance so clear that all light can go through it. When light passes through window glass, part of it is absorbed and transformed into heat energy (page 78). That is what warms the window pane on which the bright sun is shining. Part of the light is reflected, and part goes through to the other side—is *transmitted*.

Substances through which both light and images may be seen are called *transparent*. Substances through which light but not images may be seen are called *translucent*. Oiled paper and "frosted" glass, for example, are translucent. Substances which allow no light to go through are called *opaque*. Materials differ in their ability to absorb, reflect, or transmit light. This fact has an important bearing, as we shall see, on the problem of artificial lighting of homes and industrial concerns.

Reflection of Heat and Light.—Experiment 121.—(Teacher's Demonstration.)—In a darkened room reflect by means of a mirror a beam of light from a small hole in the curtain, or from some artificial source of light, on to a plane mirror lying flat upon a table. If there is not sufficient dust in the air to make the paths of the rays apparent, strike two blackboard erasers together near the mirror. Hold a pencil vertical to the mirror at the point where the rays strike it. Compare with each other the angle formed by each ray with the pencil. Raise the edge of the mirror, and notice the effect on the reflected ray. Place the pencil at right angles to this new position of the mirror, and compare the angles in each case. How do the sizes of the angles on either side of the pencil compare?

The smooth surfaces of houses often reflect so much of the light falling upon them that the glare is thrown into the windows of surrounding houses into which the sun itself cannot shine. If one stands in the right position, the reflection of trees and other objects can be seen in a smooth lake. But the reflection can not be seen if the position of the spectator is much changed. The reflected ray must therefore maintain a certain relation to the ray that strikes the surface from the object.

In Experiment 121, when the pencil was held perpendicular to the mirror at the point where the rays touched the mirror, it was seen that both the ray from the window and the reflected ray made about the same angle with it. These two angles are respectively called the *angle of in-*

cidence and the *angle of reflection*. By most careful experimentation it has been found that the angles between each of these two rays, and the line drawn perpendicularly to the reflecting surface are always equal, or in other words *the angle of reflection is always equal to the angle of incidence*. (Figure 121.) This

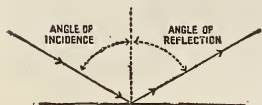


FIGURE 121

explains why, if you are standing in a room at one side of a mirror, you can see in the mirror only the opposite side of the room. We are accustomed to

a similar law of reflection when we bounce a ball on the floor for some one on the opposite side of the room to catch.

Experiment 122.—Obtain three large squares of paper of the same shade, whether white or colored. Let one be glossy, one dull, and one rough. Hold them up in succession against the darkest wall of the room. Which seems to reflect most light directly to the eye?

The rougher a surface is the more it scatters or *diffuses* the light. Figure 122 shows how the light shining on a rough surface is reflected in so



FIGURE 122.—SHOWING HOW REFLECTED LIGHT IS DIFFUSED (SCATTERED) BY A ROUGH OR ETCHED SURFACE

S-S, smooth surface; R-S, rough surface

many different directions that it does not produce glare.

Should the walls of a living room be finished glossy or dull? Which is likely to be more tiring to the eye, a book printed on glossy or on dull-finished paper?

What Makes Objects Differ in Color.—**Experiment 123.**—Obtain pieces of cloth of a number of different colors. Darken the room and light a Bunsen burner. Adjust the holes at the bottom so that it will give but little light. Dip a glass rod in a solution of common salt and place it in the flame of the burner. The flame will be colored a brilliant yellow. Now examine the colors of the different pieces of cloth. Do they appear as they did in sunlight?

The color of a non-luminous substance is due to the kind of light it transmits or reflects. If a colored object is looked at by lamplight it will not appear of the same color as by sunlight because the lamplight is deficient in some of the colors of sunlight. Therefore the object cannot reflect the same combination of colors when exposed to lamplight that it reflects when exposed to sunlight.

If, for example, an artificial light lacks red rays, then a red surface exposed to it would absorb all the colors of the light and would appear black because there are no red rays to be reflected.

A surface is white because it reflects all colors. A surface is black because it absorbs all colors. In general, the darker a surface is, the more light waves it absorbs.

The Effect of Color in the Lighting of a Home.—Certain colors absorb more of the visible light waves and reflect less light than other colors do. Deep browns, deep reds, deep greens, and deep blues absorb from 65% to 85% of the light waves that fall upon them. They are, therefore, good colors for sun-porches where not so much reflected light is needed. But they are poor colors for north rooms, which the sunlight never reaches directly.

To get the *maximum* light in a north room, the walls and ceiling should be finished in white. This reflects 80% of the light back into the room. But white seems "cold." Yellow, orange, and the lighter reds (pinks) are the colors of sunlight that convey the impression of warmth. These all reflect more than 50% of the light waves that fall upon them, and they are the colors best suited to rooms into which the sun never shines directly.

Buff has been found to be in many ways the most satisfactory of all colors for the walls of a sunny living room. It reflects about 60% of the light without producing the glare of a white surface. Moreover, it reflects enough yellow

light to make the room cheerful. Ceilings are generally finished in white or in very light shades, because the reflected light comes from above and does not strike the eye directly.

Refraction of Light.—Experiment 124.—Place a penny in the center of a five-pint tin pan resting on a table. Stand so that only the farther edge of the penny can be seen over the edge of the pan. Have some one slowly fill the pan with water. How is the position of the penny apparently affected? (Figure 123.)

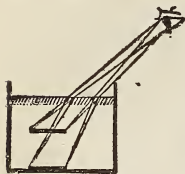


FIGURE 123

Experiment 125.—Fill a tall jar about two-thirds full of water. Place a glass rod or stick in the jar. Does the rod appear straight? Pour two or three inches of kerosene on the top of the water. What effect does this have on the appearance of the rod?

In the experiment of the penny in the dish, the water in some way bent the ray of light and made the penny come into the line of sight when it could not be seen before the water was there. The penny was apparently lifted up. This illustrates why ponds and streams look shallower than they really are.

This experiment shows that when light is passing from one medium to another it does not always travel in the same straight line. Certain media offer more resistance to the passage of light than others and are called *denser* media. It is this difference of resistance which causes the bending of the ray.



FIGURE 124

Suppose that a column of soldiers marching in company front are passing though a corn field and come obliquely upon a smooth open field. (Figure 124.) The men as they come on to the open field are unencumbered by the

cornstalks and will move faster, and thus the line of march will swing in toward the edge of the corn field. It can easily be seen that the bending of the line would be in the opposite direction if the soldiers were marching from the smooth field into the corn field. If the company front were parallel to the edge of the corn field, then the men would reach the open field at the same time and there would be no swinging of the line.

The above illustration roughly explains what happens when light passes from one medium to another. *Refraction* is the name given to this bending of light in passing through different media or through a medium of changing density. Twilight, mirage, the flattening of the sun's disk at the horizon, and other appearances, we shall find later, are due to this property of light.

If rays of light pass through a piece of window glass both surfaces of which are smooth, the rays will enter and leave the glass in parallel lines. But if one side of the glass is roughened (etched), the rays will be refracted in so many different directions that the light is diffused. (Figure 125.) Through such a glass, light but no image is transmitted. The scattering or diffusion of light by the rough surface also prevents glare.

A piece of ice may be used to illustrate the effect of etching glass. A smooth, clear piece of ice is transparent and reflects light with a glare. But if the surface be roughened by chopping it fine, both the reflected and the transmitted light from the ice are diffused.

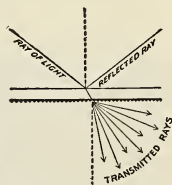
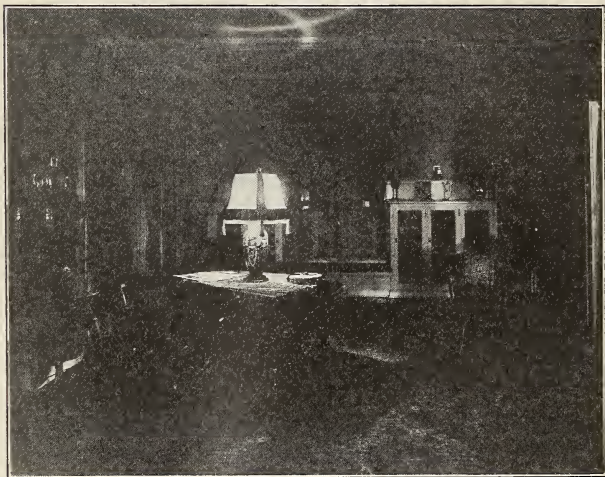


FIGURE 125.—SHOWING HOW TRANSMITTED LIGHT IS DIFFUSED (SCATTERED) BY A ROUGH OR ETCHED SURFACE OF GLASS

Systems of Lighting.—Etched glass has many uses. It is frequently used in office and school room doors not

only to admit light but to retain privacy. But it finds its most important use in the various systems of lighting.

In the *direct lighting system*, lights are so placed that their rays fall directly on the surfaces to be lighted. This is the system found in most homes. Its chief disadvantage is that it produces uneven lighting—glaring lights in cer-



Courtesy Curtis Lighting Inc.

DIRECT LIGHTING BY MEANS OF A TABLE LAMP

tain spots and gloom in others. To avoid glare, and to diffuse or distribute the light, “frosted” or etched glass bowls that enclose the lamp should be used. If this is not possible, it is always possible to obtain “frosted” incandescent lamps.

In the *indirect lighting system*, an opaque bowl with a reflecting interior is placed close to a white ceiling. The light from the lamps in the bowl is reflected to the ceiling.

The ceiling and walls reflect and diffuse the light in such a way as to produce a subdued light without any glare and with no marked shadows.

The *semi-direct system* combines features of both the direct and indirect systems. A translucent bowl containing the lamps is suspended from the ceiling. This reflects light to the ceiling and also allows some light to pass down-



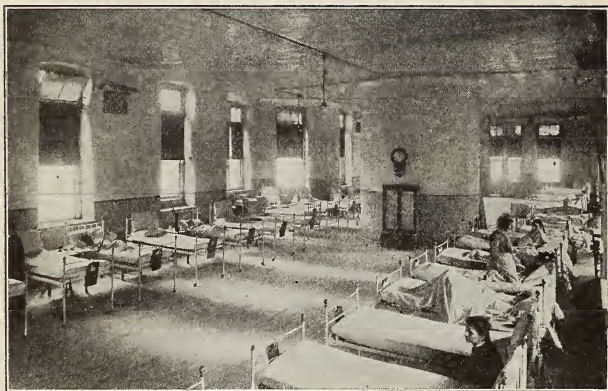
Courtesy Curtis Lighting Inc.

SEMI-DIRECT LIGHTING

This is the same room and the same lamp, with equipment to throw the light to the ceiling and to diffuse (scatter) it over the whole room. On the whole, this is more attractive for a home than indirect lighting. Enough light comes directly through the shade to show off the fixture.

ward into the room. The light coming indirectly by reflection and directly through etched glass is diffused so as to give a subdued, restful effect, with soft shadows. This system is rapidly becoming more popular and is fortunately displacing in many homes the glare of direct lighting.

Daylight in the Home.—No arrangement of artificial light is as easy on the eyes or as reliable as daylight, where colors are to be worked with or where careful measurements or minute adjustments are to be made. In work of this kind, rooms with windows on the north side, through which only diffused light will come, are preferable to rooms lighted by south windows.



HOSPITAL WARD

Showing the great care taken to secure light, air, and cleanliness.

In early days when few people were able to get glass for windows, houses were dark and gloomy. At present, however, glass is cheap and there is no reason why houses should not be well lighted. Few houses are built nowadays without making generous allowance for window space. All modern manufacturing buildings have the major part of their outside walls devoted to windows. Hospitals are so planned that every possible room may have direct sunshine for at least a part of every day. We are beginning to appreciate the value of abundant sunlight.

Dampness and darkness are the two conditions favorable

to the growth and activity of bacteria. Few disease germs can live if exposed to the direct light of the sun. No house can have too much sunlight. There should be no dark corners to harbor germs. Kitchen cupboards and sinks should be so located, if possible, that they may receive direct sunshine. Bedclothes, rugs, hangings, clothing, should all be exposed to the bright sunlight as often as possible. Sunlight not only kills disease germs; it also banishes gloom and stimulates cheerfulness. Cheerfulness itself is a genuine health tonic.

IV. SOME USES OF LENSES

Experiment 126.—Hold an ordinary spectacle lens such as is used by an elderly person, or any convex lens, between the sun and a piece of paper. Vary the distances of the lens from the paper. The heat and light rays from the sun are bent so that they converge to a point. Try the same experiment with a lens used by a short-sighted person, or a concave lens. This lens does not have the same effect as the convex lens. The rays are made to diverge.

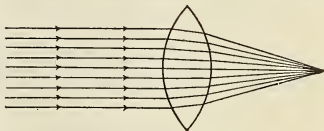


FIGURE 126.—DOUBLE CONVEX LENS

Lenses.—The bending of light in passing from one medium to another has been turned to great advantage in the use of lenses. In the making of lenses, transparent substances are so shaped that rays of light which strike them are bent into any desired direction. Experiment 126 shows that the rays may be brought nearer together (converged or focused)



FIGURE 127.—DOUBLE CONCAVE LENS

by a convex lens, or spread farther apart (diverged) by a concave lens. If the illustration of the line of march of the soldiers is kept in mind, it will be seen that the rays

must always be bent toward the thicker part of the lens. (See Figures 126 and 127.)

No matter what kind, size, or shape of lens is made, their chief use is to furnish aid to the human eye.

How a Convex Lens Produces an Inverted Image.—

Experiment 127.—(Teacher's Demonstration.)—Place a lighted candle on a table. On a wall or rack about four feet distant, fasten a sheet of white paper. Darken the room. Hold a reading glass



FIGURE 128. SHOWING HOW A READING GLASS THROWS AN INVERTED IMAGE ON A SCREEN

near the candle in such position that light will pass through the glass and fall on the white paper screen. Figure 128. Move the reading

glass back and forth slowly until a clear inverted image of the candle is formed on the paper.

In Experiment 126, we found that *parallel* rays passing through a convex lens are bent, or refracted, toward each

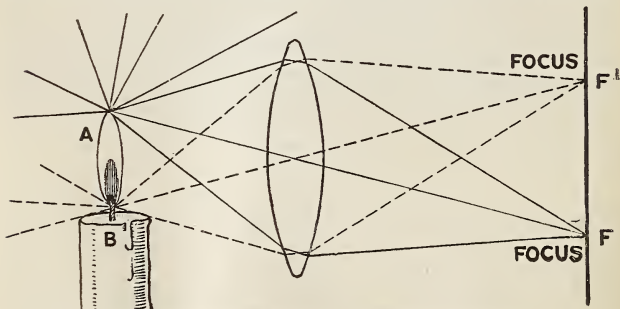


FIGURE 129.—CANDLE FLAME FOCUSED ON A SCREEN

other until they meet at a point or focus. (Figure 126.) Now let us see how *rays spreading out from a point* are gathered by a convex lens and focused at a point (as in Experiment 127) on the other side of the lens.

In Figure 129, at A, the rays of light are seen traveling

in all directions from the tip of the flame. Those rays that strike the convex lens are gathered to a focus on the other side of the lens at F . The rays of light from B , the base of the flame, are also traveling in all directions. Those rays from this point that strike the convex lens are gathered to a focus on the opposite side at F^1 . When the reading glass was in the right position, rays from every point of the flame were being brought together and focused

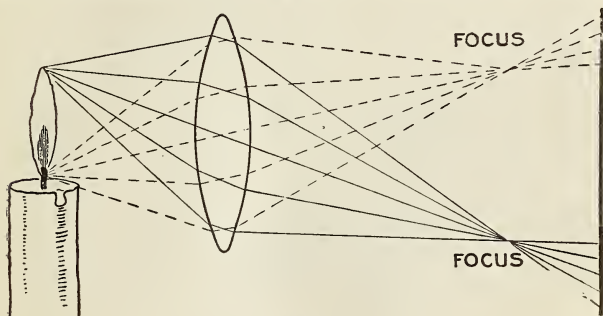


FIGURE 130

at a corresponding point on the paper. That is why an image was formed. Trace the rays from A and from B and you will see why the image is inverted.

Why the Position of the Lens Is so Important; Focusing.

—Repeat Experiment 127. When you have the lens in position to form a clear image on the screen, move it slightly either toward the candle or toward the screen. In either case, is the image clear or blurred?

Figure 130 shows what happened when the screen was too far from the reading glass. The transmitted rays from all points of the object met at their foci and spread again, thus blurring the image. When the screen was too close (Figure 131), the result was the same, because the rays

transmitted from all points of the object had not yet met at their foci.

The Camera.—The two preceding experiments explain why a good camera is so devised that the position of the lens may be adjusted. This arrangement makes it possi-

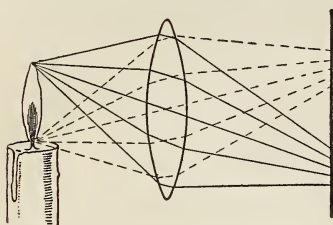


FIGURE 131

ble to move the lens back and forth until a clear image is formed on the photographic plate at the back of the camera. The inside walls of a camera are always black so as to prevent blurring of the picture by reflected light.

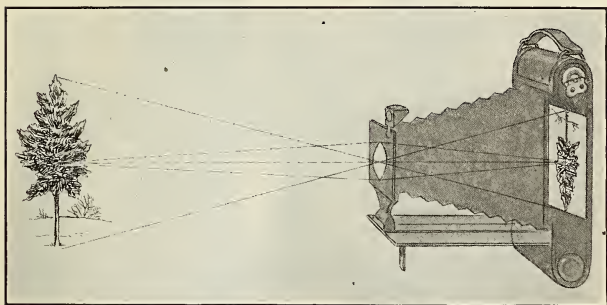
It may be asked why a lens is necessary at all in a camera, since an inverted image of an object may be produced through a pin-hole. Through a pin-hole, comparatively few rays of light may pass, and so the image is dim.

But a lens is many times the diameter of a pin-hole. The larger surface of the lens, therefore, catches many more rays of light reflected from the object than can pass through a pin-hole. These many rays of light are bent inward by the lens to a focus, thus forming a much brighter image than can be obtained through a pin-hole.

The *plate* or *film* on which the image is thrown is covered with a chemical that is affected by light. The speed with which light does its work on this plate depends on its intensity. The size of the hole through which light passes may, therefore, be regulated. Moreover, the *shutter*, which admits and cuts off the light, is so devised that light may be admitted for any length of time, from a fraction of a second on a bright day to hours of exposure at night.

The stronger the light is, the more the plate is affected,

and so the light parts of an object or a scene appear darkest on the photographic plate. That is why the plate is called a *negative*. When the picture is printed from the negative on paper that is also sensitive to light, the dark shadows on the negative cut off the light and produce corresponding light places on the print. Thus the print has the same lights and shadows as the original object or



Courtesy Eastman Kodak Company

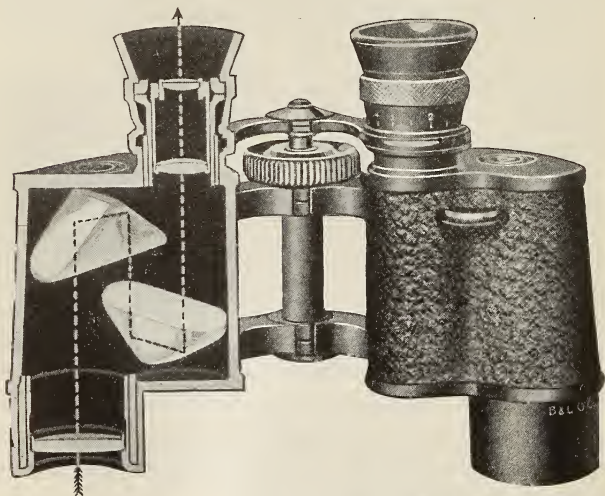
DIAGRAM OF A CAMERA SHOWING AN OBJECT FOCUSED ON THE FILM

scene. The fixing of the image both on the negative plate and on the positive print, so that it will not fade out, is accomplished by means of chemicals.

The Telescope and the Microscope.—In the astronomical telescope and in the compound microscope, lenses or lenses and mirrors are combined. In an astronomical telescope, a very large lens or a very large mirror is used to gather the greatest possible number of light rays from a distant object. These are focused in a long tube to form a small bright image. This small bright image is spread out or magnified by other lenses. The result of the combination of lenses is a bright magnified image. Galileo's telescope was a marvelous thing in its day. It gathered more than eighty times the amount of light that could

enter the unaided eye. Yet that first telescope was little better than our toy telescopes to-day.

In the compound microscope, the whole purpose of the combination of lenses is to spread out the rays of light



Courtesy Bausch and Lomb Optical Co.

A PAIR OF BINOCULARS

To get the same results without prisms, the barrels of this instrument would have to be as long as the path of the light ray that is shown by the dotted line.

coming from a tiny object so as to produce a larger image. In a compound microscope, the light by which the object is to be examined is reflected by a mirror facing the object lens.

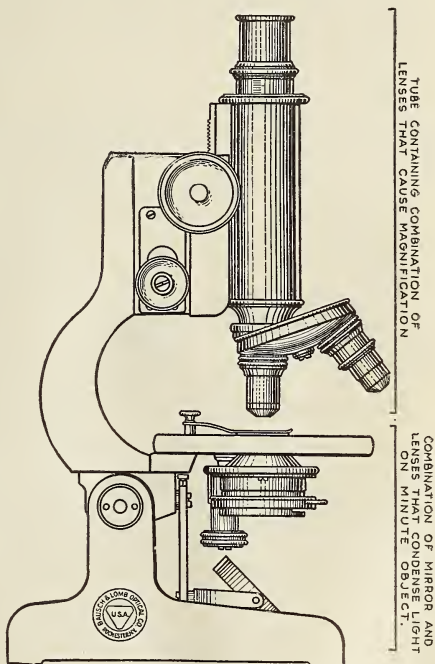
The Human Eye.—The organ of sight, the *eye*, is an exceedingly sensitive, automatically adjustable camera that records through the nerves. The camera box consists of the coats or coverings that surround the eye

(Figure 132). The *eyelid* is the shutter. The *iris* is the membrane in the front of the eye which opens or contracts to let in more or less light. In the center of it is the adjustable opening, the *pupil*.

Back of the iris, is a small adjustable *lens* and beyond this the sensitive plate, the *retina*. Between the iris and the front of the eye is a waterylike material, the *aqueous humor*, which keeps the front of the eye extended into its rounded form. Back of the lens is a thick, transparent, jellylike material, the *vitreous humor*, which holds

the retina extended and keeps the eye from collapsing.

Instead of moving the retina back and forth to focus a picture, as is done with the ground-glass plate in a camera, the eye lens is capable of adjusting itself so as to focus objects which are at different distances. Leading back



Courtesy Bausch and Lomb Optical Company
A COMPOUND MICROSCOPE

to the brain from the retina is the *optic nerve*, which carries the impressions made on the retina to the brain, where they are interpreted into the sensation of *sight*.

This rough comparison is by no means a description of the eye, for it is a most complex and wonderful organ, vastly superior in construction to a camera.

Defects of Vision.—Sometimes the lens is not able to focus a picture distinctly on the retina, and then it is necessary to aid the lens of the eye with artificial lenses, or glasses.

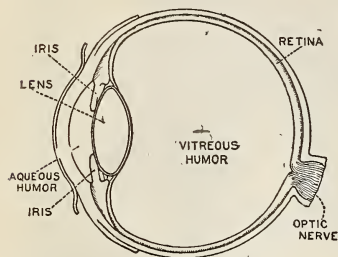


FIGURE 132.—DIAGRAM OF THE HUMAN EYE

Figure 133, N, shows a normal eyeball. It is of just the right length from front to back to receive an image on the retina with the least necessary adjustment of the crystalline lens.

If an eyeball is too short from front to back (Figure 133, F-S), the rays of light from the points of a near-by object have their foci back of the retina. See also Figure 131. Such an eye needs a convex lens to bend the rays inward so that they will meet on the retina. This is called *far-sightedness*. A far-sighted person sees clearly objects that are at a distance, but finds that ordinary print or small objects close at hand appear blurred.

If an eyeball is too long from front to back (Figure 133, N-S), rays of light from the points of an object reach their foci in front of the retina. See also Figure 130. Such an eye needs a concave lens to spread the rays so that they will meet farther back, on the retina. This defect is called *near-sightedness*. A near-sighted person can plainly see

objects placed very close to the eye, but can not clearly distinguish objects at a distance.

Sometimes the curvature of the eyeball is imperfect. Defective vision arising from this cause is called *astigmatism*. Figure 134 furnishes a test for astigmatism. To a normal eye these lines running in different directions should be sharply defined and equally dark. Anyone who sees some of these lines sharply defined and black while others are blurred and of lighter shade probably has astigmatism. He should at least consult a reliable oculist.

Silly notions about one's personal appearance in glasses should never stand in the way of wearing glasses when they are necessary. If there is a strained feeling when the eyes are used, or if headaches result from continued use of the eyes, reliable advice should be sought.

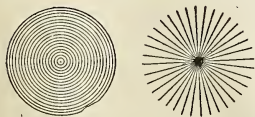


FIGURE 134.—DIAGRAMS USED IN TESTING FOR ASTIGMATISM

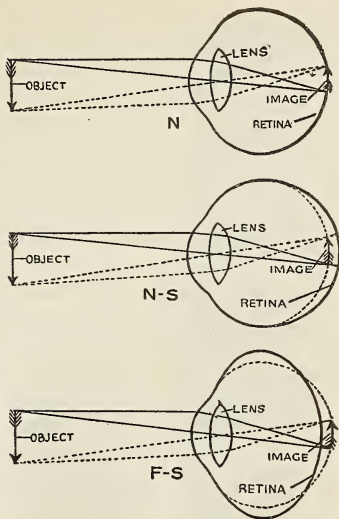


FIGURE 133.—DIAGRAMS SHOWING A NORMAL, NEAR-SIGHTED, AND A FAR-SIGHTED EYE-BALL

To correct near-sightedness, a concave lens must be used to spread the rays so that they will focus farther back. To correct far-sightedness, a convex lens must be used to gather the rays together so that they will focus farther forward.

Care of the Eyes.—The eye is so important for our usefulness and happiness that the greatest



SECTION OF A
"MOVIE" FILM

Notice that it requires
nine pictures to
bring the chair up
to a horizontal posi-
tion.

care should be taken of it. One should not read when he is lying on his back, when the light is either poor or glaring, or when the book can not be held steadily. The eye may be infected from public washbowls, public towels, or even by rubbing with one's own fingers. Any infection of the eye demands skillful treatment and should not be trifled with.

The Moving Picture.—An impression made on the retina remains for an instant, probably about one-twelfth of a second; and so if successive pictures (about sixteen a second) are taken of a moving object and projected on a screen at the same rate the eye will not distinguish the intervals between the pictures and the object will appear to be in motion. This is the way in which moving pictures are produced.

SUMMARY

The most important thing we know about light is that life is absolutely dependent upon it. Carbon is needed as food by the rooted plant and this is obtained by the plant leaf from the carbon dioxide of the air. Water and soil foods meet carbon dioxide in the leaf cells. The green substance called chlorophyll, principally in the leaves of plants, is able to utilize the energy of sunlight to combine the food elements into plant food.

Plants are able by the arrangement of leaves or varying exposure of their surfaces to adapt themselves to their supply of light. Leaves also adapt themselves to the supply of moisture. The manufacture of food can go on in the plant leaf only when light is present. For this reason plants kept in darkness starve to death. In the manufacture of its food the plant throws off an excess of oxygen. Animals use the oxygen and breathe out carbon dioxide as a waste product. Thus the gas returned to the atmosphere as waste or surplus by one form of life is useful to the other.

The development of artificial lighting has had tremendous bearing on extending man's activities and increasing his efficiency. Man's first artificial light was the bonfire. The moss wick in a bowl of fat was the forerunner of the candle, which up to seventy-five years ago was the best light obtainable. The invention of the kerosene lamp was the next great step in advance, and was the most common form of lighting until about 1885, when the invention of the gas mantle made gas lighting very efficient. In recent years electric illumination has been rapidly replacing all other forms of lighting.

Light travels in a straight line through a uniform medium. We see non-luminous bodies by reflected light. The intensity of light varies inversely as the square of the distance from the source. We should never face a strong light nor read in the glare of too strong a light. Light may be absorbed, reflected, or transmitted. When light is reflected, the angle of incidence is equal to the angle of reflection.

The color of a non-luminous object depends on the kind of light it transmits or reflects. Colors that convey the impression of warmth should be used in north rooms. Sunshiny rooms may be decorated in darker shades that absorb more light. When light passes from a medium of a given density to another medium of greater or less den-

sity, the rays are bent or refracted. The bending of light rays in passing from one medium to another is turned to great advantage in systems of lighting and in the use of lenses, which may be so constructed as to bend rays of light in any desired direction. No matter what the kind, size, or shape of lens its chief use is to furnish aid to the human eye.

The eye is an automatically adjustable camera, but vastly superior in construction to any mechanical camera. Defects of near-sightedness, far-sightedness, and astigmatism are caused by imperfections in the shape of the eyeball.

QUESTIONS

How does the plant obtain the carbon it needs?

By what means are food materials obtained from the soil and from the air manufactured into food for the plant?

In what ways do leaves adapt themselves to their supply of light?

How do leaves adapt themselves to their supply of moisture?

Why does a rooted plant die if it is deprived of light?

How do plants and animals serve each other?

What were the only forms of lighting known up until about seventy-five years ago?

How are the various oils of petroleum separated from one another?

Why is kerosene a safer fuel than gasoline?

How are gas mantles made? Why does a mantle add so much to the efficiency of gas lighting?

In what direction does light travel through a uniform medium?

Why are non-luminous objects visible?

What is the amount of light necessary for a study table?

What is the law of reflection of light?

What makes objects differ in color?

What causes refraction of light?

Explain the direct, indirect, and semi-direct systems of lighting.

What is the final purpose of all lenses?

Describe a camera.

Compare and contrast the human eye with a camera.

CHAPTER XV

PLANT LIFE

*To me the meanest flower that blows can give
Thoughts that do often lie too deep for words.*—Wordsworth.

Relation of All Sciences to Life.—All the subjects we have studied in this course are interesting and valuable primarily because of their relation to life. Heat, light, and other forms of energy, air, water, chemical and physical change, our relations to the heavenly bodies, the surface of the earth, soils, weather, winds, and climate furnish the sum total of conditions that make life possible. The chief aim of modern science is to enable man to exercise greater control over his surroundings; in order to make life more comfortable, to lengthen its span, and to furnish more leisure for the enjoyment of things worth while.

No living thing is so small that it is unimportant. Before the invention of the microscope and the modern development of the science of chemistry, man knew no living friends or enemies except those he could see with his naked eye. The biologist with his microscope has discovered teeming millions of minute life-forms; and the chemist is able to show the presence of still other life-forms too small for the microscope to reveal. During the last half century we have learned to cultivate some of these low forms of life as friends and to battle others as deadly enemies. During these last fifty years, in fact, so much progress has been made in studying the activities of living things that the

discoveries of this period outweigh those of all the preceding centuries.

Characteristics of Living Things.—We have spoken (page 333) of *protoplasm* as a living material. It is *the only living material*, and its presence and activity account for all the differences that exist between living and non-living things. In appearance, protoplasm may be best likened to the white of an egg. A molecule of protoplasm is composed of hundreds of atoms. It is made up chiefly of carbon, hydrogen, oxygen, and nitrogen (page 336), but potassium, iron, calcium, sulphur, and phosphorus are elements necessary to its existence.

Protoplasm exists in any living organism in innumerable cells. In fact the body of every living thing is made up of cells and of the materials that the cells manufacture. Living cells are so small that there was never a thought of their existence until the microscope revealed them. Each cell is surrounded by a protective covering called the cell-wall, but it has the power of communicating with neighboring cells.

Scientists have learned that cells may exist in any living organism for many different purposes. In the higher forms of life, each kind of cell has a definite kind of work to do, and it does nothing else. Countless cells may be grouped according to the work they have to do. These groupings we speak of as *tissue*. In man, for example, we speak of muscular tissue, nerve tissue, brain tissue, etc.

The protoplasm of the cell has the power of *growth*; that is, the power to increase itself. Growth is accomplished by increase in the number of cells. When a cell reaches a certain size, it may divide into two cells. The cells in the young plant or animal do not differ in size from those of an older and larger organism; they differ only in number.

The protoplasm of the cell also has the power to *manufacture* materials needed by the living organism; for example, the woody tissue of plants and the bony tissue of animals. Protoplasm is also capable of *repairing* wounded or worn-out tissue. When the bark of a tree is injured healthy cells immediately set about repairing the injury. So with injuries to the skin, the protective covering of animals; repair of a scratch or wound is the work of healthy cells.

In short, cells are the seat of every activity of every living thing.

I. INDEPENDENT PLANTS

Although in their lower microscopical forms it is very difficult to distinguish between plants and animals, yet the forms ordinarily seen differ greatly. Most visible plants are fixed and consist of root, stem, and leaves, while most animals are self-moving and possess a variety of different parts. But some plants, like the seaweeds, appear to have no roots; some, like the dandelion, no plant stem, and some, like the cactus, no leaves.

The higher forms of plants and animals are alike in that (1) both need air, water, and other kinds of food, (2) both take in, digest, and assimilate food, and (3) both have parts which are particularly adapted for doing these different kinds of work.

If we dig around the base of a tree, we find in the soil a network of *roots* holding firmly erect a pillar-like *stem* with



A TYPICAL PLANT
Showing root, stem, leaf,
and flower.

branches bearing a profusion of *leaves*. Each division has a distinct part to play in the life work of the tree.

We have seen how roots and leaves take in raw materials and have learned how plants with chlorophyll are able to change these raw materials into food that supports both plant and animal life. The plants that have chlorophyll and that with its aid manufacture their own food are called *independent plants*.

We have yet to study the work of *plant stems* and to see how the plant; by means of *flower* and *seed*, reproduces itself.

Stems.—Experiment 128.—Obtain a cornstalk. Cut a cross section of the stalk. Notice the outside hard rind, the soft pithy material, and the small firmer points scattered about in the pith. Cut a section lengthwise of the stalk and notice how these small firmer points are related to the lengthwise structure of the stem.

Cut off a young growing cornstalk and place the cut end in water colored by eosin or red ink. Allow it to stand for some time and then cut the stalk off an inch or two above the surface of the water. How have “the firmer points” been affected? If possible, make the same observations and experiments on the stem of a small seedling palm tree.

Experiment 129.—Obtain a piece of the growing young stem of a willow, apple tree or other woody stem. Cut a cross section of this stem and examine it. Does it resemble the cross section of the cornstalk? Strip off a piece of the bark and compare it with the rind of the cornstalk. Examine carefully the smooth, slippery surface of the wood just beneath the bark. This is the *cambium layer*.

Examine the firm wood beneath this layer. Where is the pith in this stem? With a lens you may be able to see lines radiating from the pith to the circumference of the stem. These are called the *pith rays*. Cut a lengthwise section of the stem and examine it. Are there any fiberlike bundles as in the cornstalk? Cut off a piece of the stem already examined having the bark on it, or a piece of sunflower stem, and place the end of it in colored water. Allow it to remain for some time and then cut a cross section above the point where it was in the water. Has the water risen and colored this cross section exactly as it did the cross section of the cornstalk?

There are two great types of stems, one represented by the cornstalk and palm and the other by the willow, sunflower, and bean. On account of the structure of the seeds these are called, respectively, *monocotyledonous* (one seed leaf) and *dicotyledonous* (two seed leaves). That these differ greatly in their appearance was seen in Experiments 128 and 129, where the two kinds of stems were compared. It was also found in these experiments that, in the first, the



A DICOTYLEDONOUS AND A MONOCOTYLEDONOUS LEAF

red colored water that took the place of the sap rose in the fibrous bundles scattered through the pith, while in the second it rose through the woody tissue close within the bark.



CROSS SECTION OF
YOUNG BOX ELDER
BRANCH

Notice the pith at the center and the pith rays running from the bark to the pith.

Growth of the Stem.—When the bark is removed from a stem, like the willow or apple, the soft, smooth layer underneath is found to be composed of living cells. This is the *cambium layer*, where rapid growth takes place in the stem. In the center of the woody stem is the *pith*. This is made up of large thin-walled cells. In the young stems, the

pith serves as a storage place for food. In the older plants the pith dies, because the stem and the roots are able to store all the food necessary for the plant. The *pith rays*, which in the young stem connect the pith with the cambium layer, also store food and serve as a means

of communication between the inner and outer portions of the stem.

During the season of growth, the cells of the cambium layer are continually subdividing to form new cells. The cells of this layer increase in both directions, adding both to the woody material underneath and to the overlying bark. On the inner side of the cambium layer, the cells



Courtesy U. S. Forest Service

OPENING LEAVES AND BLOSSOMS OF THE HORSE-CHESTNUT

thicken their walls with woody material. These wood-walled cells either grow into elongated hollow fibers to strengthen the stem or unite with other woody cells above and below to form continuous hollow tubes for carrying up the stem the water absorbed by the roots.

On the outer, or bark side of the cambium layer, thin-

walled cells are formed which carry digested food downward toward the roots. As the new living cells are added to the bark, the older ones are crowded outward. These older cells gradually thicken their walls with a wax-like material which furnishes a corky protective covering for the plant stem. This covering grows so thick in the cork oak of Spain, Portugal, and northern Africa, that it is peeled off and sold as the cork of commerce. When the cells of the bark have thickened their walls into corky material, and the cells on the inner side of the cambium layer have built their walls of wood fiber, the living matter of the corky and woody cells has accomplished its work, and so it dies.

Experiment 130.—Examine several growing stems or twigs which have buds upon them and notice how the buds are arranged. Is the arrangement the same in all? If these buds grew into twigs or leaves, would they shade one another? Is there a bud at the end of the twig or stem?



PINE TREE

Note the erect stem.

If we examine the tip of a growing stem or twig, we shall find a *bud*. In most of the trees and shrubs of temperate regions a terminal bud is formed at the close of the growing season, and from this the shoot continues to

grow in length the following season. Buds are also found along the length of the stem and branches, as was seen in Experiment 130. These are lateral buds and, since they



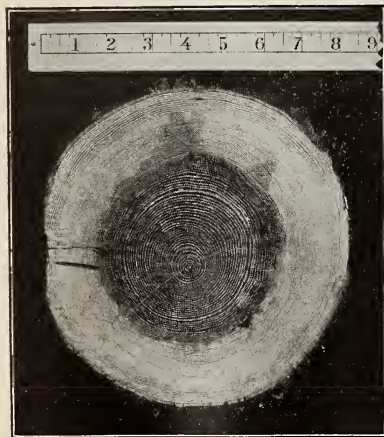
FIGURE 135

are usually found in the axis of the leaf, at the angle formed by the leaf and stem, they are called *axillary*. Flowers, leaves, and branches develop from these buds. In some



FIGURE 136

trees the terminal buds die at the end of the growing season, and the next year's lengthening of the stem has its origin in one of the axillary buds.



Courtesy U. S. Forest Service

CROSS SECTION OF THE TRUNK OF A WHITE ASH

From Otsego County, New York.

This fine specimen shows the rings of growth and the distinction between heartwood and sapwood.

The Work of the Stem.—Stems vary greatly in the positions they assume. Some rise firmly erect from the root, like the oak and the pine; some cling to supports, like the grape and the ivy; some twine around supports, like the bean; some creep upon the ground, like the strawberry; some grow in the form of a thickened bulb like the onion

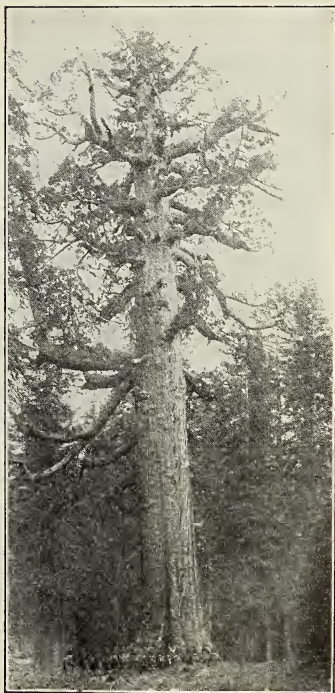
(Figure 135); some, like the cacti, assume a fleshy, leaflike, though leafless form; some, like the nut grass, Johnson grass, and witchgrass, grow underground and send up

shoots, and some stems store up food underground in tubers, like the potato (Figure 136), from which the next year's plant may grow.

Notwithstanding all the diversity shown by the stem, its principal functions are to support the leaves, so that they will best be exposed to the light, to conduct food elements in solution from the roots to the leaves, to convey the manufactured foods from the leaves down toward the roots, and to store foods for the future use of the plant.

Trees.—Experiment 131.—Examine a cross section of a hardwood tree several years old, and if possible of a palm. Notice the ring-like arrangement of the layers in one and the absence of all such arrangement in the other.

If you have had opportunity to examine the face of a stump or the cross section of a hardwood tree, you know that, from the center outward, it is made up of rings of wood. The pith may have disappeared entirely, leaving only a hole at the center of the



REDWOOD TREE

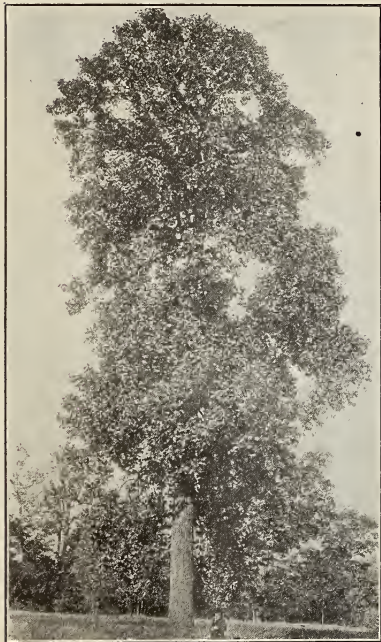
This is the monarch of all plants. This particular tree is 93 feet around the base. Notice the troop of cavalry at the foot of the tree.

log or stump. No such rings are found in the cross section of a monocotyledonous tree.

Closer examination reveals that each ring consists of two parts—a layer of softer, lighter-colored wood, sur-

rounded by a thinner layer of harder, and generally darker, wood. The softer layer represents the rapid growth of spring; the harder layer, the slower growth of summer. The two together represent a year's increase in the girth of a tree—a year's work of the cambium layer. The age of a tree can be determined by counting these rings.

How old the oldest redwoods of California or the cedars of Lebanon in Asia Minor are, we do not know. But many stumps that are over two thousand years old have been



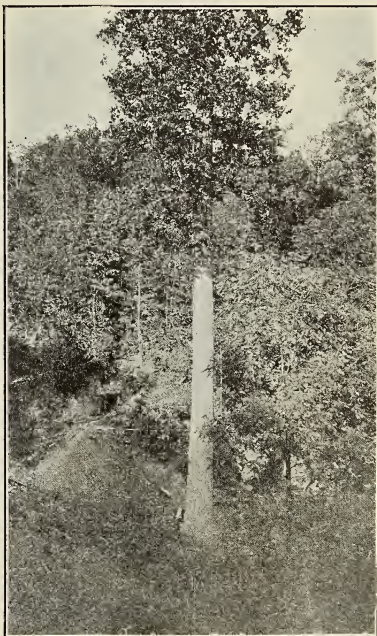
Courtesy U. S. Forest Service

TULIP TREE
Washington, D. C.

found, and some that are more than three thousand years of age.

At the center of a stump or cross section of a tree, the wood is harder, more durable, and generally darker than

the wood of the outer rings. This dark hard center is called the *heartwood*. As the tree has grown older, the tubes in the heartwood have ceased to carry water and have become filled with gum, resin, coloring material, and even mineral matter. The purpose of this heartwood is, like that of the bones of the human body, to add strength to the living structure. The lighter-colored outside layers of wood are called the *sapwood*, because it is through the tubes in these layers that the sap is carried upward. In cedar chests we frequently see the striking contrast between the red heartwood and the lighter-colored Sapwood.



Hardwoods and Softwoods.—Lumbermen divide woods into two

classes, softwoods and hardwoods. The softwoods come from the trees of the pine family, cone-bearing trees—roughly speaking, the evergreens. Hardwoods are from the broad-leaved trees which lose their leaves in autumn.

Courtesy U. S. Forest Service

YELLOW POPLAR

Lee County, Virginia.

The terms are inaccurate. Georgia pine, for example, which is classed as a softwood, is relatively hard; while certain "hardwoods," such as cottonwood, basswood,



Courtesy U. S. Forest Service

MAGNOLIA TREE IN BLOOM
Franklin Park, Washington, D. C.

poplar, and willow, are among the softest of woods. Certain "softwoods," such as the cedar, the cypress, the white pine, and the redwood, while they are really soft, are among the most durable woods known; that is, they best resist the bacteria of decay.

Written Report.—Familiar Woods and their Commercial Uses. See suggested references in the Appendix.

Voluntary Project.—To become acquainted with two hitherto unfamiliar trees and to tell how to identify them. References in the Appendix.

How the Plant Reproduces Its Own Kind.—Experiment 132. —Examine a flower of a buttercup, quince, cassia, or geranium. It will be found to be made up of four distinct kinds of structures.

Around the outside is a cluster of greenish leaves. This is called the *calyx*. Within the calyx is the *corolla*, a cluster of leaves which in many plants are colored. Within the corolla are a number of parts consisting of a rather slender stalk with an enlarged tip. This tip is called the *anther*, and the stalk and anther together, the *stamen*.

In the center of the flower are the *pistils*. At the top of a pistil is generally a somewhat enlarged portion, the *stigma*, which is sticky or rough; and at the bottom there is an enlarged hollow portion, the seed-bearing part, called the *ovary*. These two parts are connected by the stalklike *style*.



TYPICAL FLOWER

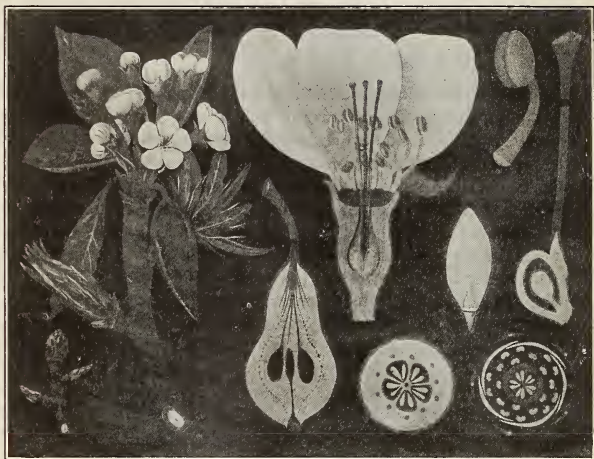
This shows the various parts of a flower. The base is cut away to show the seeds in the ovary.

The stem not only bears leaves but, in the higher kinds of plants, it bears *flowers*. The function of the flower is to produce seeds and provide for the continued existence of its kind. The stamens and pistils are the essential parts of the flower, the calyx and corolla being simply for protection or assistance. All flowers do not have these four parts, but every flower has either stamen or pistils or both.

The anther produces a large number of little granular bodies, called *pollen grains*, each of which consists of a free cell containing protoplasm. When the pollen grains are

ripe, the anther opens and exposes them. If a pollen grain of the right kind falls upon a stigma it grows and sends down a tiny tube through the style into the ovary, where a little protoplasmic cell, called the *egg cell*, has been produced. The essential parts of these two different kinds of protoplasm unite and a new cell is formed.

This new cell grows and divides into more cells, thus



THE LIFE STORY OF A PEAR

Twig, bud, blossom, and fruit.

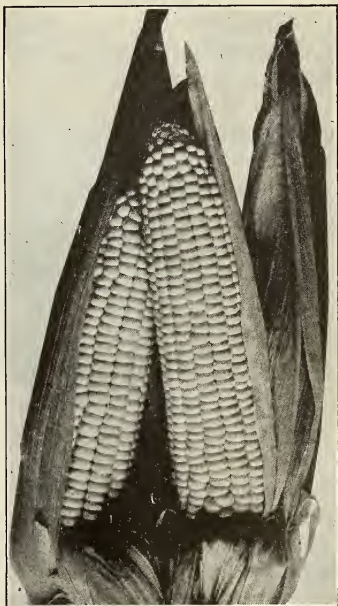
forming the young embryo of a new plant. This embryo is the living part of the seed and around it usually a great deal of plant food is stored, so that when it begins to grow it will have plenty of nourishment until it is able to develop the roots and leaves necessary to prepare its own food.

Embryos cannot be produced unless pollen grains and egg cells unite, so it is absolutely essential that the right kind of pollen grains be brought to the stigma.

When the stigma of a flower has received suitable grains of pollen, it is said to be *pollinated*. Some stigmas are able to use the pollen grains produced by the anthers of their own flowers. Such flowers are said to be *self-pollinated*. Others can use pollen only from flowers of other plants. Plants of this sort are *cross-pollinated*.

The Service of Winds and Insects.—In the case of cross-pollination, it is necessary that the pollen grains be carried about from flower to flower if fertile seeds are to be produced.

In some cases the pollen is borne about by the wind, as in the case of corn. In this way an exceedingly large number of pollen grains are wasted, as can be seen by the great amount of yellow pollen scattered over the ground of a corn field when the corn is in bloom. In the corn the tassels produce the stamens. Each one of the corn silks is a pistil and a seed is produced at its base if a pollen grain from a corn tassel lights upon the stigma at its upper extremity. The flowers of walnut and apple trees are fertilized by wind-blown pollen. Flowers of some varieties



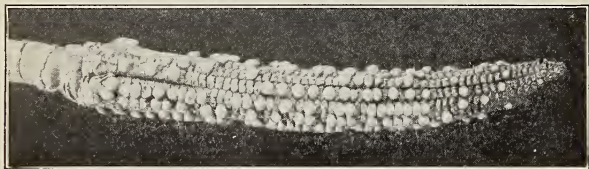
EFFECT OF COMPLETE POLLINATION

Each kernel results from the falling of a wind-blown pollen grain upon a corn silk.

of plants cannot be fertilized by flowers of a like variety. Certain varieties of strawberries, for example, need to have other varieties planted near them, if they are to prosper. The Spitzenberg apple blossom must be pollinated by another variety of apple blossom in order to produce fruit. For that reason orchards in Oregon are planted with rows of Spitzenbergs between rows of other varieties, such as Baldwins or Jonathans.

Some plants need not only to have other varieties planted near, but they also require the presence of special insects.

The pollen of very many plants is carried about by



EFFECT OF POOR POLLINATION

humming birds, bees, and other insects. As the bee crawls into the flower to get the nectar at the bottom, it brushes against the anther and some of the pollen grains become attached to it. These, later, are rubbed off by the rough or sticky stigma of another flower which the bee enters and thus the flower is fertilized. The humming bird, by reaching its long, slender beak down into the long, narrow tube formed by the corolla of the "wild honeysuckle" brushes upon the stigma the pollen grains it has obtained from another flower and thus distributes pollen from flower to flower. In no other way could these plants be fertilized.

The beautiful colors of flowers and the sweet nectars that many of them secrete are the adaptations of the plant for enticing insects to enter them and bring to their stigma

the pollen from other flowers, or take from their anthers pollen needed to fertilize another similar plant.

Some flowers are so constructed that only certain insects can fertilize them; the wild honeysuckle requires the humming bird, the red clover the bumblebee and other plants, other kinds of insects.

One of the most striking examples of this is the Smyrna fig. For many years attempts were made to introduce this fig in California.

The trees grew but the fruit did not mature.

It was then observed that in the regions where this fig was successfully grown a species of wild fig was abundant and that the natives were accustomed to hang branches of the wild fig in the Smyrna fig trees at the time they were in flower. These wild fig trees were brought to California] and grown near the Smyrna fig trees, but still figs did not mature. Upon further examination it was observed that at the time of flowering a small



BUTTERFLY ON ALFALFA

insect issued from the wild figs and visited the flowers of the Smyrna figs. This insect was brought to California where now it is possible to grow figs. The flower of the Smyrna fig has no stamen and it is necessary for the wild fig to furnish the pollen which is only successfully carried

to the stigmas of the edible fig by the small fig-fertilizing insect.

A somewhat similar case is that of the yucca found in the dry region of southwestern United States. This flower can be fertilized only by the aid of a small moth which flies about at night from flower to flower. It enters the flower, descends to the bottom, stings one of the ovaries, deposits an egg, then ascends and crowds some pollen on the stigma. The grub, when it hatches from the egg, feeds on the seeds in the ovary, but as there are many seeds in the flower which have been fertilized and the grub eats only a few of these, the moth has made it possible for the yucca to produce seeds sufficient for its continued propagation, which would be impossible if it were not for the moth.

These are only a few of the vast number of cases which show the close relationship existing between plants and animals and the dependence of the one upon the other.

Seed Dispersal.—Not only must flowers produce fertile seeds, if the plants are to continue to exist, but these seeds must be scattered. To do this the seed pods of some plants suddenly snap open and spread their seeds. The touch-me-not and pea are examples of this. In some plants, like the maple, the seeds are winged (Figure 137) and float for some distance in the air. Others, like the thistle and the dandelion, have light, hairlike appendages



FIGURE 137

which enable them to float away. In the case of the tumbleweed the plant itself is blown about, scattering the seeds over the fields as it bumps along from place to place.

Some seeds are provided with hooks or barbs, like the beggar's-ticks (Figure 137), which attach the seeds to animals so that they are carried to a distance. Seeds having an edible fruit cover, such as the cherry, black-

berry, and plum, are eaten by birds and animals and the undigested seed deposited far away from the place where the seed grew. Seeds like the acorn are carried about by squirrels and other animals. Many seeds are able to float in water for a considerable time without being injured and are borne about by currents. Shores of streams and islands receive many of their plant seeds in this way. The cocoanut palm is a notable seed of this kind and is found widely scattered over tropical islands.

Seeds and Their Germination.—Experiment 133.—Take two common dinner plates and place in the bottom of one of them two or three layers of blotting paper and thoroughly wet it. Place some wheat or other kinds of seeds upon this. Now invert the other plate over the first, being careful to have the edges touch evenly. This makes a moist chamber and gives the most favorable conditions for germination. Do all the seeds germinate at the same time? Does the position of the seed make any difference? What takes place first in the process of germination? What appears first, the leaf or the root? Does the seed shrivel up?

Experiment 134.—Cut open several seeds, such as pumpkin, squash, bean, corn, and drop on to the inside of each a few drops of the iodine solution made in Experiment 112. Do the seeds show the presence of starch?

Experiment 135.—Soak some beans for about twenty-four hours. Rub off the skin from two or three and examine their different parts carefully. Plant the beans in a box of damp sawdust. Put the box in a warm place. Plant in the same box some corn that has been soaked for two or three days. After the seeds have been planted several days, carefully remove a bean and a grain of corn and examine. Make a sketch of each of the seeds.

After a few days more remove another seed of each and examine and sketch. Continue to do this until the little plants have become well developed. Do the two seeds develop alike? Which of the seeds has two similar parts? These two parts are called *cotyledons*. What appears to be the use of these parts to the sprout? Consult the results of Experiment 133. Note the root development in each seed and the stem development. The sprouts get their food from the seed.

When we examined the different seeds in Experiment 134, we found that they each contained starch. When

the seeds were soaked and planted, we found that a part of the seeds began to grow, forming a *sprout*. This part is the embryo already described. We also saw that the bean seed divided into two like parts which gradually withered and shrank, as the sprout grew, while the corn had only one such part.



FIGURE 138

These parts are called *cotyledons*, or seed leaves. The bean seed (Figure 138) is a *dicotyledon* (two seed leaves) and the corn a *monocotyledon* (one seed leaf). These cotyledons are the food storehouses for the germinating seed. As the sprout grew, the root, with its root-hairs, developed, and the stem with its leaves. When these had grown strong enough, the cotyledons, having performed their part,

dropped off. The plant was now ready to prepare its own food by the aid of the sunlight.

Experiment 136.—Place several beans in a tumbler of damp sawdust and put it in a warm, light place. Keep the sawdust moistened. After the beans are well sprouted, with a sharp knife cut one of the half beans or cotyledons off from a sprout. Cut both cotyledons off another sprout. Put the sprouts back in the sawdust. Do the sprouts grow as well as those of the other beans?

Experiment 137.—Fill a 16-ounce, wide-mouth bottle about one-third full of peas or beans. Pour in more than enough water to cover them. Tightly cork the bottle and put in a warm, sunny place. Put another similar corked empty bottle beside it. Allow the bottles to stand for several days until the peas have sprouted. Remove the cork from the bottle containing the peas and insert a burning splinter. Do the same to the empty bottle. Why does not the splinter burn as well in each? If on being placed in either bottle the splinter is smothered out, it shows the presence of carbon dioxide.

Experiment 138.—Fill two 8-ounce, wide-mouth bottles each about one-third full of coarse sawdust and fill the remaining part with peas which have been soaked for a day. Pour in sufficient water to cover

the sawdust. Cork one of the bottles tightly, leaving the other open. Put the two bottles in a warm, sunny place. Whenever necessary, pour on sufficient water to keep the sawdust in the open bottle wet. In which bottle do the seeds sprout the better? Does air appear to be necessary for the growth of seeds? As determined by the previous experiment, what part of the air is used?

We found in Experiment 136 that if the cotyledons were cut off before the sprout had become sufficiently mature, it could not continue its growth. In Experiment 137 we found that the sprouting seeds took up oxygen from the air and gave out carbon dioxide just as animals do. Energy was needed and this energy was obtained by combining the carbon in the seed with the oxygen in the air, as it is when wood is burned. We found in Experiment 138 that the seeds could not sprout well unless sufficient air was supplied. That was because there was not enough oxygen supplied to furnish the necessary energy.



SCRUB OAK BRANCH
Showing the acorns.

Experiment 139.—Place several sprouted seeds in each of two tumblers nearly filled with damp sawdust. Put these tumblers side by side in a warm, light place. Cover one of the tumblers with a box painted black so as to exclude the light. In which do the seeds grow the better?

After the seeds were sprouted and had begun to prepare their own food, it was found in Experiment 139 that

they were not able to do this unless exposed to the light of the sun. The parent plant had stored, in a latent form in the seed, energy which it had received from the sun. This potential energy the sprout was able to change into the kinetic form by the aid of oxygen, and to use in the work of growing. After this latent energy had been expended, it had to fall back upon the direct energy of the sun which came to it in the form of sunlight.

II. PROTECTION AND BETTERMENT OF PLANTS

All Food Plants Once Grew Wild.—Primitive men were no doubt nomadic, or wandering, creatures. They depended for their existence on whatever food plants they could find or on whatever animals their weapons could bring down. But as tribes increased in numbers, they could no longer depend on chance supplies of food. They found it necessary to plant and tend certain wild plants that had proved to be the best sources of food. All plants that man cultivates to-day come of wild ancestors, and most of the food plants have been cultivated for unknown thousands of years in Europe and the East. The only exceptions are those few plants which the western continents added to the list; notably Indian maize and the potato, and later the tomato.

Man's Interference in the Struggle for Existence.—What man did when he first began to cultivate chosen plants was to take up the battle for these plants against others. For the earth is a battle-ground for plants as well as for animals. Plants struggle with each other for room, for light, for moisture, and for soil-food.

Almost any plant if given favorable conditions, no plant competition, and no enemies, would in a few years produce enough seed to enable it to overrun a continent. But no such conditions exist for any one plant. Soil and

climatic conditions favorable to one kind of plant may be fatal to another. Moreover, under the very same conditions of soil and climate, many plants thrive equally well, and so they continue to exist side by side. Plants that have lived long together in any area eventually arrive at what is known as a *balance of life*. They live and let



OAK TREE IN OPEN FIELD

The lack of crowding has enabled this tree to develop perfectly.

live. The hardiest specimens of each kind survive and the weakest perish.

Primitive man realized that if his chosen plants were to thrive, he must keep down or keep out useless plants that grew faster, that scattered seed more abundantly, and that were less easily killed off in competition with his cultivated plants. This was the beginning of the endless war on weeds. Anxiety for the success of his crops arrayed him against certain animals that he looked on as crop destroyers. Desire to protect his domestic

animals ranged him on their side against animals that preyed upon them. And so man has done many things through the centuries to disturb the balance of life. In this war against supposed plant and animal enemies, man has made many mistakes, as we shall see in our later discussion of weeds, insects, and birds. He has often

blindly fought his real friends, and given aid to his worst enemies.



IMPROVED BLACKBERRY

The War Against Weeds.—Weeds have been defined as wild plants that have a habit of intruding where they are not wanted. Many of them are hardier than cultivated plants. Some have roots or rootstocks that spread underground, are long-lived, and hard to kill. Some weeds produce prodigious quantities of seeds, which are widely

distributed by winds, birds, and other animals. Moreover, these seeds are frequently mixed with the poorer grades of crop seeds and are sowed in abundance by the farmer.

Some weeds are confined to sections of the country. Others have been so confined but are now either gradually or rapidly spreading. The following are some of the weeds that are common to all parts of the country: bindweed, horse nettle, dandelion, dock, pigweed, poison ivy, and ragweed. The damage these and other weeds do is more than simply to crowd out the domestic plants.

Some weeds are poisonous to both men and animals. Others harbor insects and other forms of life that are enemies of the farmer's crops. Wild onion and bitterweed on grazing land spoil the taste of dairy products. The United States Department of Agriculture estimates that in one way or another weeds cost the American farmer several hundreds of millions of dollars a year.

Many things can be done on a farm to decrease the number of weeds that have to be fought. Even one farmer fighting alone can do much to discourage weed growth. Fields should never be kept too long in meadow without mowing, because weeds become firmly established under such conditions. A farmer should never plant more land to corn than he can properly care for. It pays both in time and in crop value to buy a better grade of clover and alfalfa seeds and thus avoid sowing weeds.



RAGWEED

A great many farmers very wisely mow their pasture land once or twice a year. This keeps the top growth cut off and tends to starve the weeds to death (page 358). Why? One of the mowings should be just at the time when the weeds are at full blossom. The roots are then weakest, and the chance is that new flowers and seeds

may not be produced again before frost. This cutting of tall weeds also removes the shade from the grass and gives it a chance to grow and to thicken its stand.

When in addition to the precautions mentioned, farmers regularly mow their fence-rows and hedge-rows and unite to keep down weeds on roadsides and railroad rights of way, they find themselves more than repaid eventually both in money and in time.

Why are there fewer weeds in a lawn that is regularly mowed than in an unkept lawn? Notice the position of the leaves of the plantain and the dandelion and see if you can explain why mowing does not kill them.

Note.—Any rural school will do well to send to the United States Department of Agriculture for Farmers' Bulletin No. 660, "Weeds and How to Control Them."

Disturbing the Balance of Life.—Many a plant that is harmless enough in its native surroundings may cause unlimited trouble if it is transplanted to another continent. In its accustomed home, weather, soil, plant and animal enemies have kept it from growing too fast and increasing its numbers too rapidly. In the new surroundings, a combination of more favorable soil and climate and absence of enemies may cause it to spread like a plague. It has been found by the Department of Agriculture that sixty per cent of our worst weeds have been imported from Europe. The so-called Canada thistle originated in Europe. The amount of trouble this one weed causes may give some notion of how much of our weed trouble has been imported.

The importation of the cactus or prickly pear into Australia was a real tragedy for that continent. The plant is a native of America and at home it is an innocent enough member of the plant community. In 1788 the Australians imported the cochineal insect from South America, in the

hope of starting a dye industry. At the same time the prickly pear was introduced to serve as food for the insect. The insect did not thrive, but the cactus did. If the Australians could have seen the trouble ahead, they would have destroyed it root and branch while there was yet time. Instead of that it was cultivated for hedges, chiefly because of its picturesque appearance. Now it is literally taking the land.

A single joint of the plant was taken from Sydney to Queensland in 1858. So rapid and so dense is its growth there to-day that Queensland is losing tillable land at the rate of a million acres a year, and is spending hundreds of thousands of dollars a year to be rid of the pest. The cactus grows in dense hedge-like thickets as great as one hundred feet in circumference. Poisoning, grubbing, and blasting afford only temporary riddance. The line of the enemy is pushed back but it grows forward again. Besides, these methods of fighting the pest are so expensive that cactus-infested land cannot be given away with a bonus to prospective settlers.



CANADA THISTLE

University authorities in Australia are now recommending that insects and other forms of life that prey on the cactus in other continents be imported to make war on the plant. But the forms of life that attack the cactus in America may find valuable crops in Australia much more to their liking; and so they may prove to be enemies instead of friends. When man interferes in the struggle for existence, and thus alters the balance of life, he often

encounters troubles that last for years. More will be said of this in the discussion of animals.

Wild Flowers.—There is another side to the problem of wild plants. Some that have the most beautiful blossoms are neither so hardy nor so widespread as the troublesome weeds. Such plants, which add so much



Courtesy Wild Flower Preservation Society of America. Photograph by E. L. Crandall

DOGWOOD

beauty to the countryside, are in danger of extermination by their best friend and worst enemy, man. The automobile now takes thousands of people into the country who in former days seldom saw a wild flower. As a result of the reckless gathering of flowers and destruction of plants by automobilists, many delicate growths are disappearing from our landscape.

The dogwood is a hardy tree, but twice a year it invites its stupid admirers to wreck it. To get its blossoms of

spring or its red berries of autumn, ruthless flower gatherers tear off its branches and strip its bark. Many dogwood trees are thus wounded beyond recovery. Careless forest rambles are not content simply to gather the wild flowers; they uproot the stems and pick the blossoms afterward. The mayflower, or trailing arbutus, blue flag, hepatica, blood root, lady's slipper, gentian, and

many others are among the beautiful wild flowers that are growing scarcer every year.

Preservation of wild flowers is not altogether a matter of sentiment. As these wild flowers disappear, the burdock, thistle, mustard, and ragweed take their place. Friendly insect and bird life dependent on these flowers is affected. Animal as well as plant pests are encouraged. In fact, the disappearance of wild flowers disturbs the whole balance of life unfavorably.

The Wild Flower Preservation Society of America is attempting to educate people to the preservation of such plants as those mentioned above. Among the flowers which may be picked with freedom are the daisies, buttercups, goldenrod, wild asters, California poppy, wild lilac, trumpet creeper, and many other hardy specimens. The movement to protect the more delicate wild flowers deserves the support of everybody. A good rule is to pick no beautiful wild flower unless one is sure it does not belong to a delicate disappearing variety.



*Courtesy Wild Flower Preservation Society of America
Photograph by E. L. Crandall*

TRAILING ARBUTUS

Plant Breeding.—We are no longer so much concerned with the choosing of new plants for cultivation. Modern agricultural science aims chiefly at the bettering of those

plants which have been long under cultivation. There are *three avenues* by which this work of plant improvement is carried on—the *seed, the flower, and the stem*.

Those who devote their time to discovering or originating better varieties of plants are called *plant breeders*



RESULTS OF A SEED TEST

These six kernels were under exactly the same conditions in the germinator

Plant breeders have done more in thirty years to improve the one crop of wheat alone than had been done in the previous four thousand years. A few generations ago the tomato was regarded as a poison fruit by the majority of people. The ‘love-apple,’ as it was then known, was small, watery, tasteless, and full of bitter

seeds. The large, meaty, well-flavored, rose-red tomato of to-day is the product of careful plant breeding. The poorest potatoes on the market to-day are greatly superior to the best variety of little more than a half century ago.

Buying Better Seed ; Seed-testing.—Experiment 140.—Obtain a small amount of clover or alfalfa seed. Count out one hundred seeds and spread them on a blotter cut to fit a dinner plate. Cover the seeds with another damp blotter cut to the same size. Cover the plate and its contents with an inverted plate or bowl. Keep the blotters moist but do not disturb them. Put the testing apparatus in a place where the seeds will be kept warm but not too warm. At the end of three days, examine the seeds. How many of them have sprouted?

Fifty per cent of good alfalfa or clover seed should be sprouted in such a test at the end of three days. If fewer than half show signs of life at the end of a three-day test, the seed is probably of low vitality and is not worth planting. Modern farmers always make such a test for seed vitality. They know how many of the seeds of any plant should be sprouted at the end of a given length of time.

Experiment 141.—Spread out a quantity of clover or alfalfa seeds on a sheet of white paper. Examine them with a powerful reading glass and see if there are seeds of other sorts mixed with them. Even if there are only a few, remember that these may indicate the presence of thousands of weed seeds in a bushel of crop seed.

Larger seeds are seldom adulterated with weed seeds but the smaller seeds may have many varieties of weed seeds mixed with them. To sow seed that contains many weed seeds is to sow trouble. For this reason the wise farmer avoids the cheaper grades of seeds. He knows that he will lose many times more in the harvested crop than he can possibly save by buying cheap seed. The

most economical thing a farmer can do is to buy the best seed the market affords.

Other tests that should be made are not so easily conducted. They are tests for the presence of microscopic plants that cause disease in the growing plants. Such tests—in fact, seed tests of all kinds—will be made free of charge by State Agricultural Colleges and Experiment Stations. As a result of these tests, larger crops, hardier crops, and fewer weeds are being raised by farmers to-day.

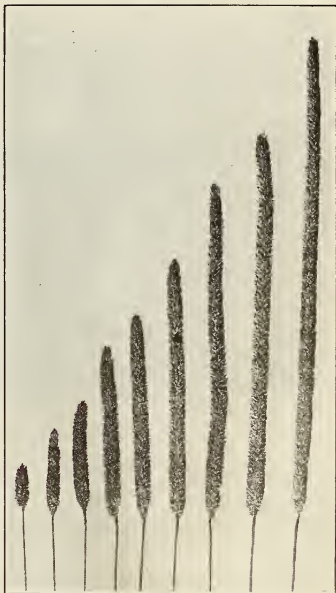
Discovering Better Seed.—Students of plant and animal life have learned two basic facts: every form of life tends to be like its parent or parents, it *inherits* certain characteristics; on the other hand, no plant nor animal is ever exactly like the plant or animal parent, it *varies* in some ways. This variation may be great or little, but it is always found in some degree. No form of life is ever exactly duplicated.

Once in a long time, the variation is so great that the offspring is vastly better than the parent plant. Such was the remarkable case of the Concord grape. In 1843, Ephraim Bull of Concord, Massachusetts, planted a few seeds of the wild fox grape, expecting to raise wild grapes. When the vines finally began to bear fruit in 1849, Mr. Bull was surprised to find that one of the vines bore a new kind of grape, superior in size, flavor, and all other respects, to the fruit of the parent vine. Although he raised after that more than 22,000 plants from seed of the wild fox grape, he found nothing to equal the one superior vine. Such an unusual plant offspring is called a *sport*. One of our best apples, the Wealthy apple, and one or two kinds of wheat are varieties from chance seeds.

If seed is produced by a self-pollinated plant, the average of plants grown from it will tend to be like the parent plant. If the parent plant had certain weaknesses

the offspring plants may be inferior to the parent. But as we have seen, a chance plant may be possessed of certain elements of strength that enable it to produce unusually fine seed.

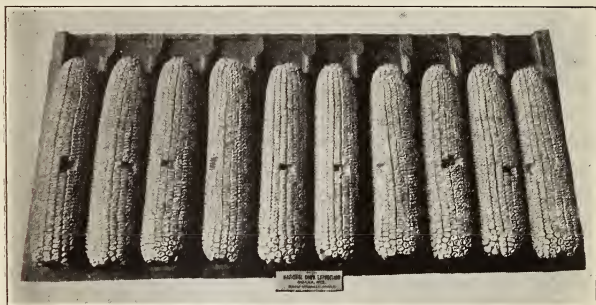
The one thing to do in maintaining a high grade of self-pollinated plants is to choose the very best seed to produce the crop of the following year. It is probable that even primitive man learned by experience to do this sort of thing. But the modern plant breeder has carried his selection of seed much further. Most varieties of wheat are self-pollinating. To improve these varieties is a matter of finding the best seed. After searching wheat fields for months or even seasons, an expert may come upon a single stalk bearing grain of an unusually fine variety. Such a stalk he treasures carefully. From the small crop raised from the grain of this stalk, he chooses the best seeds from the sturdiest plants for replanting. This process is repeated until he has a large enough quantity of seed to distribute for actual farming operations.



VARIATION IN TIMOTHY HEADS

These heads of timothy all grew within one square yard of soil. Selecting the best is the first step in plant improvement.

The Flower as a Means of Plant Improvement.—The plant that grows from the seed of a cross-pollinated plant inherits characteristics of both parents. If both plants have a tendency toward some plant disease, the young plant offspring will have an even greater tendency in that direction. If both plants tend to be free of a certain kind of blight or disease, the young plant offspring will be even hardier. If both parent plants have any desirable quality, the plant offspring will have that quality in more marked degree. It may be seen that the plant



PRIZE CORN

breeder has only to choose parent plants and to control cross-pollination in order to produce greatly improved varieties of plants in comparatively short time.

Originating Better Seed.—Since corn is one of our largest crops, it may well serve to illustrate how a plant may be improved by cross-pollination and selection of seed. Corn, like any other plant, may be cultivated for the strengthening of any one of a number of characteristics. For example, the manufacturers of corn oil products made known a number of years ago their desire to have corn with a higher percentage of oil. In response to this, the

Illinois Experiment Station proceeded to breed this kind of corn.

Well-developed ears of corn from hardy plants were chosen. Those ears that had grains showing the highest percentage of oil were chosen for planting. The grains of each ear were planted in separate rows. To produce corn of higher oil content, it was necessary that two plants grown from seeds of high oil content should be cross-pollinated. It was necessary therefore to prevent self-pollination. To make cross-pollination certain, the tassels of every other row were removed so that the ears of the detasseled rows had to receive their pollen from the tassels of a neighboring row. (Page 409.) The seed for the next crop was chosen only from the detasseled rows. From these rows the grain of highest oil content from the hardiest plants was sorted out for replanting. By repeating several times this process of cross-pollination and selection of seed, the Illinois Experiment Station eventually produced a variety of corn with twice the oil content of the average crop.

This method has been used for strengthening various unit characteristics of corn, such as large starch content, ability of the plant to endure drought, ability to grow in cool surroundings, ability to resist disease, etc.

Some years ago, certain cotton-growing areas of the South were invaded yearly by a kind of blight which attacked the roots of the cotton plants and destroyed the crop. On investigation, experts of the United States Department of Agriculture found that occasional plants resisted the disease, came to maturity, and produced seeds. They selected seeds from these hardy plants, raised plants from this seed, and cross-pollinated the flowers. By repeating this process through several generations of plants, the Department produced a variety of cotton which was not subject to this particular kind of blight.

In cases where the plant breeder is not able to obtain

cross-pollination on a large scale, as in the case of corn, he carries on cross-pollination on a more limited scale. He selects the best possible plant for his purposes. Before



CORN BAGGED
To keep off inferior pollen.

the flowers have matured, he ties paper bags over them to keep off pollen-bearing insects. As soon as the flowers open, he carefully clips off the unripened stamens and ties the bags in place again to wait until the stigmas ripen. When the stigmas are ready to receive pollen, the experimenter chooses the best plant for his purposes, and with a camel's hair brush transfers pollen from its stamens to the stigmas of the protected

flowers. The pollinated flowers are again tied up to await the ripening of the seeds. These seeds are planted and the whole process repeated until a superior breed of plants is obtained.

Plant Improvement by Way of the Stem.—Seeds cannot always be depended upon to produce plants of as high order as the parent plant. And so in case of shrubs and trees, which have been improved by selection or cross-pollination or which have grown from a chance seedling, it is often necessary to reproduce by grafting or by cuttings. Cuttings are twigs or branches which are planted and tended until they become rooted.



STEPS IN THE PROCESS OF GRAFTING

Grafting and budding are processes of bringing the cambium layers of two trees of similar kinds in contact and keeping them protected until they grow together. These operations are performed as shown in the accompanying illustrations. A bud or a piece of stem of a choice peach tree, for example, is attached to the stem of a hardy tree that bears less desirable fruit. The tree is called the *stock*, and the new growth from the grafted stem or bud is called the *scion*. All fruit borne on the stems that develop from the scion is like the fruit of the tree from which the stem or bud was taken.

The continued production of seedless oranges is altogether dependent on budding. This fruit was originally a sport discovered in Brazil. All the seedless oranges in America come of two trees imported from Brazil in 1870. The very name of this orange indicates that it can not be reproduced from seed. It is therefore necessary to propagate it by budding. The seeds of a hardy variety of orange are planted. When a seedling

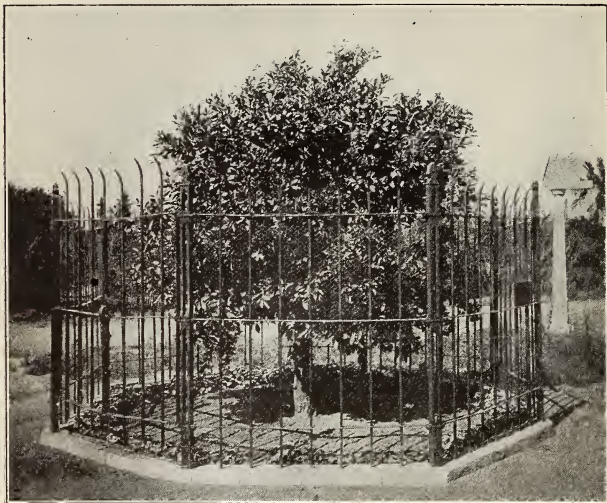


Courtesy California Fruit Growers Exchange

BUDDING AN ORANGE TREE

Hardy orange trees are grown from seed in a nursery and the seedling trees are budded as shown in the picture. The bud is inserted in a slit made in the branch of the seedling tree and then held in place with wrappings of waxed cloth. After the scion has begun to grow, the branches of the seedling are pruned away.

plant reaches the age of two years, buds from a seedless orange are inserted in the two-year-old plant. As soon as shoots grow from these buds, the natural branches of



Courtesy California Fruit Growers Association

NAVEL ORANGE TREE

This is one of the parent trees brought to southern California nearly fifty years ago.

It is still producing good fruit, although it has furnished budwood for many acres of navel orange plantings.

the seedling are cut back so as to allow only the budded shoots to develop into limbs and branches. On these scions the seedless fruit grows.

Luther Burbank.—Foremost of all Americans in the production of better plants was Luther Burbank. He was born in Massachusetts in 1849 and died in California in 1926. He carried on most of his great work at his home in Santa Rosa, California. His keen

mind, coupled with unusual powers of observation, and habits of perseverance would have assured him success in any work he might have undertaken. But his somewhat delicate health compelled him to choose an out-of-door life.

While hoeing potatoes one day at his old Massachusetts home, his attention was attracted to an extraordinary seed



SEED BALLS AND FLOWERS OF THE POTATO PLANT

ball on a potato vine of lusty growth. He guarded this vine very carefully, harvested the seed, and from it eventually produced the Burbank potato, which has increased the American potato crop to the extent of millions of dollars. This was the beginning of Mr. Burbank's career as a plant breeder.

At the age of 26, he moved to California where he could work under more favorable conditions. He worked by all methods, selection of seed, artificial cross-pollination, budding and grafting. One of his notable products, the plumcot, is the result of cross-pollination between a plum

and an apricot. This *hybrid* fruit resembles both the parent fruits, but has some very desirable qualities that are all its own.

His famous Prunus berry is a cross or hybrid between a dewberry and a Siberian raspberry. The Shasta daisy, six inches in diameter, and the ten-inch poppy are among his most interesting developments in flowers.

In conducting an experiment he often grew plants by



LUTHER BURBANK

Fotograms Photo

At his home in Santa Rosa, California

the thousand. Sometimes he produced a new and desirable fruit or flower in a few experiments. Sometimes he persevered for years before he obtained the desired results. In all, he conducted over a hundred thousand series of experiments. It would require a separate volume simply to enumerate the things he achieved.

III. DEPENDENT PLANTS

The plants that we have so far studied are green plants and contain *chlorophyll*. They are able to prepare their food from the air and soil by the aid of the sun's energy. There is, however, another great group of plants which may be called dependent plants. They have no chlorophyll and are obliged to live upon the food that green plants have prepared. They find this food either in the living or in the dead parts of plants or animals. If plants live upon living plants or animals, they are called *parasites*, if upon dead ones, *saprophytes*. Some dependent plants are both parasites and saprophytes.

The mildew on lilac leaves and on the leaves of fruit trees and shrubs is a parasite. The mistletoe is a partial parasite that grows on the branches of certain hardwood trees. It is dependent on the tree for moisture and mineral food from the soil, but it also manufactures food in its green leaves.



CORN SMUT

This affects stalk, tassel, silk, husks, and kernels.

The corn smut, the smut on oats and barley, the potato blight, the scabs on apples and potatoes, and the rusts on grain are parasitic plant growths. The wheat rust alone costs the United States millions of dollars each year. Many other diseases of plants are the work of parasites. Many diseases in animals and in man are also caused by parasites. Among these are the dread anthrax, which

may attack man or his herds; tuberculosis; diphtheria; pneumonia; and smallpox.

The beautiful Indian pipe is a saprophyte which grows in low swampy places. Other saprophytes are the bacteria of decay, including soil bacteria, the mold on foodstuffs, mushrooms, and yeasts.

Oral Report.—Why should the common barberry shrub be destroyed in all grain-growing regions? Farmers' Bulletin 1058 (5¢). See Appendix.

Most of us are familiar with some of the larger dependent plants, or fungi, such as the mushrooms (Figure 139) and toadstools.



FIGURE 139
MUSHROOM

Mushrooms are widely used as a delicacy and their growth is an important industry in some sections. They are grown in soils very rich in humus and generally in dark, cellarlike places. The mushrooms that grow wild in the woods are abundant in some localities but should not be used for food unless most carefully examined by some one who is expert in determining the different species. There are

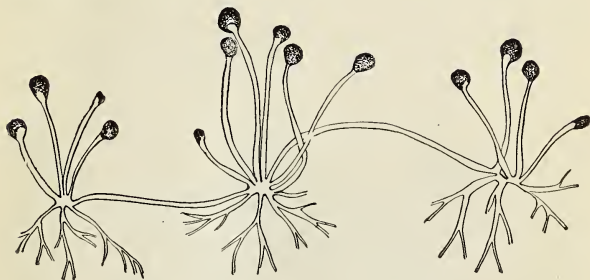
several species of mushrooms which are exceedingly poisonous. For one of these there is no known antidote. The general structure of these larger fungi¹ can be seen by examining a mushroom obtained from the market.

Molds.—**Experiment 142.**—Expose a piece of moist bread to the air for a short time and then put it into a covered dish so as to retain the moisture. Does any change take place in the bread? Examine with a magnifying glass the mold which appears.

Molds are made up of many cells. If the mold on bread is allowed to grow for a long enough time under favorable circumstances, you will note a fine black powder that forms. The particles of this powder are *spores* (seedlike bodies)

which will themselves grow into molds if favorable conditions are offered. Mushrooms reproduce by means of spores.

Yeasts.—**Experiment 143.**—(Teacher's Demonstration.)—Make a solution of molasses and water. Place some yeast in it and put the mixture away in a warm place. Watch it for a few days, and after gas bubbles have been coming off for some time put the solution in a



BREAD MOLD. (Greatly Magnified)

flask connected with a distilling apparatus as shown in Figure 89. Gently heat the solution and collect the distillate. Smell of the distillate. What does it smell like? Dip a piece of cotton cloth in it and touch a lighted match to it. If the experiment has been successful, the distillate will burn. If not, distill some of the distillate again. Alcohol and carbon dioxide are produced by the action of the yeast on the molasses and the alcohol is evaporated by low heat and condensed in the still.

Yeasts are single-celled plants, as are bacteria, but they do not increase as bacteria do. A little bud forms on the side of the yeast cell, which grows until it finally separates from the parent cell. In this way a single yeast cell may produce several other yeast cells, whereas a single bacterium may only divide into two.

If the materials and the temperature are right, as in the preparation of bread, the yeast plants multiply very rap-

idly, feeding upon the material of the dough, and changing sugar into carbon dioxide and alcohol. Little bubbles of carbon dioxide gas are developed throughout the dough, making it slightly porous.



YEAST
(Highly
Magnified)

The dough is then kneaded to develop the elasticity of the gluten and to mix the greatly increased number of yeast plants uniformly through the mass. It is then set aside again so that the uniformly scattered yeast plants may continue their activities. Bubbles of carbon dioxide form throughout the whole mass, and a light spongy dough results.

When this is heated in the oven, the tiny bubbles of gas expand, making a more porous sponge, the alcohol evaporates, and the dough bakes, thus forming light bread.

Baking powder and a combination of soda and sour milk are often used as substitutes for yeast in making biscuits and cake. Baking powder contains baking soda and cream of tartar. Cream of tartar mixed with soda acts like an acid. Sour milk contains an acid. Refer to the home method of performing Experiment 27 and explain the action of these substitutes.

Bacteria.—We have already learned something of the activities of the bacteria of decay (page 306), and realize the service they perform. We have also seen that soil bacteria and nitrogen-fixing bacteria are tireless servants of the farmer (page 339). There are many other kinds of bacteria, and the relations of many of them to man are of great importance.

The *bacterium* is a single-celled dependent plant, probably the simplest of all plants; it can be seen only with a high-power microscope. Bacteria are rod-shaped, thread-shaped, screw-shaped, or have various other

forms. The protoplasm in the cell of a bacterium has the power to assimilate food and build more protoplasm. When the cell has grown sufficiently, it divides into two cells.

Bacteria vary in their rates of growth. All of them divide frequently if favorable conditions of moisture, temperature, air, and food are present. A bacterium may divide into two bacteria in from twenty to thirty minutes, and each of these may divide again in the same length of time.

If a bacterium divided only once an hour and each division continued to divide once an hour, in the course



BREAD MAKING IN MEXICO

of twenty-four hours there would be nearly seventeen million bacteria produced from a single bacterium. If this were kept up for some weeks, the mass of bacteria would be as large as the earth. Of course, this would mean that each bacterium had plenty of room to live in and plenty of food to live on and nothing to injure it. These conditions are not found, and each bacterium has to struggle for existence just as every other plant does. As it is, however, bacteria are numberless.

How Some Bacteria Survive Unfavorable Conditions.—To flourish, or even to exist, most bacteria need to have continuously favorable conditions. But a few kinds of bacteria have a way of living through unfavorable conditions. The living matter in the cell becomes rounded and enclosed in a heavy wall. This heavy-walled body, called a *spore*, may exist inactive for a long time, without proper food, moisture, or air supply. Spores may even survive boiling or freezing. When favorable conditions



PEACH ROT

A disease caused by dependent plants.

return, the spores shed their heavy walls, and begin to grow and to multiply again.

Bacteria That Change Food.—If it were not for microscopic plants, food would keep indefinitely without change. These little plants are, however, present everywhere and if conditions are suitable for their growth they begin at once to change or to “spoil” all foods they can reach.

Experiment 144.—(1) Bruise a sound apple and place the bruised part in contact with a thoroughly rotten apple. __ Wrap the two to-

gether in a wet cloth and put in a fruit jar. Seal the jar to prevent the water from evaporating. (2) Plunge a pin repeatedly first into a rotten apple and then into a sound one. Wrap the sound apple in a wet cloth and seal in a fruit jar. (3) Place a lemon which has developed a green, spongy, rotten place in it in contact with a perfect lemon and keep them where they will be moist. What happens to the sound fruits?

Most of the minute plants which cause changes in food render it unfit for man's use. We have found that decay,



PLUM ROT

Caused by microscopic dependent plants. This picture shows four stages from left to right.

which is caused by bacteria, is on the whole a friendly process. But we look upon it as an unfriendly process when it results in the souring of milk, the tainting of meat, the spoiling of eggs, and the rotting of vegetables—all of which are due to the activities of bacteria.

Some of the bacterial changes make food more palatable, for it is bacteria that give the fine flavors to the best butter and cheeses and the gamy flavor to certain kinds of meat. Bacteria also change cider into vinegar.

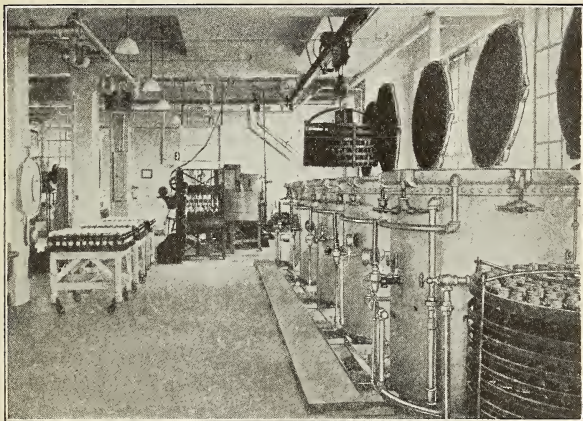
Experiment 145.—Place a slice of freshly boiled potato in each of six clean, 4-ounce, wide-mouth bottles. Close the mouths of the bottles with loose wads of absorbent cotton. Place five of these bottles in a sterilizer and sterilize for half an hour. Allow the sixth bottle to remain unsterilized. A sterilizer can be made by taking a covered tin pail and putting into it a false bottom of wood or metal grating to keep the bottles off the bottom of the pail. An inverted pie tin, with holes punched in the bottom of it, will serve the purpose. There must be holes so that the boiling water will not upset the tin. Put water in the bucket to the depth of two or three inches. Place the bottles in the sterilizer, cover it, and keep the water boiling for thirty minutes.

A reliable, inexpensive sterilizer is the pressure cooker shown on page 194.

Take the bottles out and allow them to cool. Remove the cotton from one of them for several minutes and then replace. Run a hat pin two or three times through the flame of a Bunsen burner to sterilize it and place it in the water of a vase which has had flowers in it for some time. Carefully pulling aside the edge of the absorbent cotton stopper in the second bottle, insert the pin and place a drop of the vase water on the surface of the piece of potato. After having sterilized the pin again, rub it several times over the moistened palm of the hand and then, using the same precautions as before, scratch the potato in the third bottle. Put a fly in the fourth bottle, using the same precautions. Keep the fifth bottle just as it was taken from the sterilizer as an indicator, that is, to see whether the bottles were thoroughly sterilized. Put all of the bottles away in a warm place and observe them each day for several days. The spots appearing on the pieces of potato are bacteria colonies.

Since bacteria and fungi cause the “spoiling” of food, and since certain bacteria develop poisons called ptomaines which make the eating of the food infected very dangerous, it is necessary that food be protected as far as possible from bacteria and that their growth be checked. Food should never be handled except with clean hands; it should be most carefully protected from dust and flies and kept in a clean, cool place. Most bacteria do not thrive where it is cold.

Preserving Food.—When it is desired to preserve food for a long time, especial care must be taken. Either the bacteria in the food must be entirely destroyed and the food absolutely protected from other bacteria, or else the growth of the bacteria must be completely checked.



Courtesy of Beech-Nut Packing Co.

STERILIZING CATSUP AND CHILI SAUCE

The metal baskets filled with bottles of chili sauce and catsup are lowered into the sterilizing tanks, which are constructed on the principle of the pressure cooker. Notice the abundant lighting and scrupulous cleanliness of the room.

It has been found that thoroughly drying food will protect it against bacteria; that freezing or smoking fish and meat preserves them. Fruits, vegetables, and eggs can be kept without spoiling where the temperature is maintained at a little above the freezing point. Salt, vinegar, and spices act as preservatives. Fruits placed in strong sugar sirups do not spoil. Fruits and vegetables heated for a considerable time at a boiling temperature and then tightly sealed in sterilized cans will keep.

In order to keep bacteria from spoiling meat, borax is

sometimes used. Formalin is sometimes put into milk to keep it from souring, and benzoate of soda into catsups for the same reason. These three substances act as preservatives, but *they also make the food unwholesome* and so we have pure food laws prohibiting the use of such preservatives for foods.

Written Reports.—1. The cold-pack method of preserving vegetables was very popular during the recent Great War. What is the method and why is it no longer recommended by the United States Department of Agriculture for home canning of vegetables? "Home Canning of Fruits and Vegetables." Farmers' Bulletin No. 1211, 5¢.

2. Send five cents to the Department of Agriculture and obtain a copy of Miscellaneous Circular No. 25, "Directions for Examining all Canned Food before Use." Make a brief written report of the recommendations of this circular. This may well be done by every member of the class in the interest of safety first in the home.

Bacterial Diseases.—Out of the fifteen hundred or more kinds of bacteria that are known, only about seventy may grow in our bodies and make us ill. Most of the others are man's efficient helpers. These disease-causing bacteria, however, may cause a vast amount of trouble. The



FOUR KINDS OF DISEASE BACTERIA
(Greatly Magnified)

microscopic plants and animals that cause disease are commonly called *germs*.

Almost all disease germs get into the body through a break in the skin or through the mouth or nose. The skin when unbroken is a splendid germ armor. When it is broken the bacteria have a chance to enter. In the majority of cases there are not enough hostile bacteria at hand to make serious trouble; but there is always a chance of their being present, and so all wounds ought to be cleansed, disinfected and dressed with absorbent cotton, or some

similar substance. We found in Experiment 145 that absorbent cotton kept the bacteria out. If wounds are not given careful attention, blood-poisoning, which is a bacterial disease, may set in. Sometimes when a rusty nail or other dirty substance breaks through the skin, bacteria are carried into the flesh. If such a wound is not properly disinfected and cared for, lockjaw, another bacterial disease, may be developed.

By getting into the body through the mouth or nose, bacteria cause many other diseases. Among these are influenza (grippe), diphtheria, pneumonia, whooping-cough, typhoid fever, and tuberculosis. People having diseases of these kinds throw off a great number of bacteria. If such germs get into the bodies of other people, they may cause the same diseases there. Disease germs usually do not float in the air for any great distance from the diseased person. But danger lurks in handling articles infected by germs, from eating infected food, or from drinking infected water.

Preventing the Spread of Infection.—All dishes and utensils used by persons having infectious diseases should be kept by themselves, washed in boiling water, and not used by other people. All contaminated bedding and clothing should be thoroughly washed in some disinfectant, boiled if possible, and hung for some time in direct sunlight.

So closely are people brought together in our towns and cities that carelessness on the part of one may endanger many, and it is particularly necessary that regulations be enforced which shall protect society from the careless spreading of disease. In some very virulent diseases, such as smallpox or diphtheria, the patients ought to be kept to themselves, quarantined, their rooms and everything about them disinfected, and every precaution taken

to prevent people susceptible to the diseases from being exposed to the germs.

This can not and ought not to be done in all cases of bacterial disease, since adequate protection can be given if sufficient care is taken by the person affected. If tubercular patients will carefully cover their mouths with cloths when coughing or sneezing and see that the cloths are burned, tubercular germs will cease to be a menace to society. Although thousands are afflicted each year with tuberculosis, largely through the carelessness of those having it, the disease is coming to be more readily preventable and curable. If the same precautions are taken in whooping cough or grippe, or ordinary "cold," the infection will not be spread.

How to Disinfect.—Most bacteria thrive best at a moderate temperature (70° to 95° F.) Almost all of them are killed if kept at a boiling temperature for a short time. They can not grow where there is no moisture, and all but a few kinds are killed by complete drying. Direct sunlight is soon fatal to them.



FORMALDEHYDE
CANDLE

Used for disinfecting
rooms

For disinfecting wounds, iodine or a dilute solution of carbolic acid or lysol serves well. (These must not be taken internally.) Hydrogen peroxide is a good external cleanser, but it is not a reliable disinfectant. Cinders may often be washed out of the eye and the eye disinfected with a dilute solution of boracic acid. Strong disinfectants should never be used in the eyes or nose. A solution

of listerine is a safe mouth wash.

For disinfecting sinks or washbowls a generous quantity of boiling water containing a small amount of carbolic acid

or lysol is very effective. Chloride of lime is the most common disinfectant for sewage pipes leading from bathrooms. Woodwork and wall fixtures may be wiped with a dilute solution of carbolic acid or formalin. It must be remembered that some of these household disinfectants are deadly poisons if taken internally.

Chemical disinfection of a sick room after the patient's recovery from an infectious disease is not practised in so many diseases as formerly. Continuous disinfection of everything that comes in contact with the patient is now required. If this requirement is met, the room is generally safe for occupancy by the time the patient is free from infection. Soap and water, sunlight and air are the only disinfectants needed in the great majority of cases.

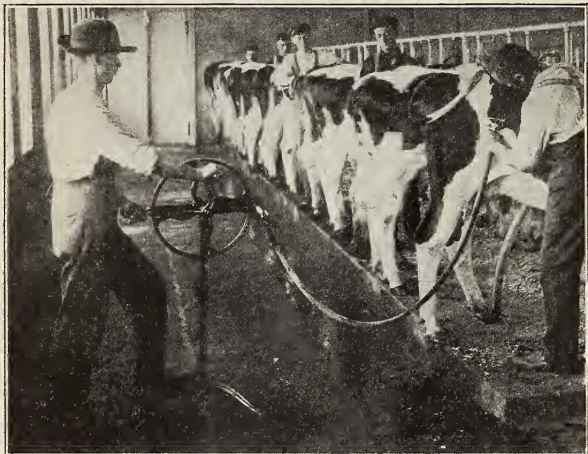
But the bacteria of some diseases, such as smallpox and infantile paralysis, have never been identified. We do not know how these germs enter the body or leave it. In such diseases, most health departments insist on chemical fumigation of a room after the patient's recovery.

Dangers from Infected Food.—If foods are handled by diseased persons or by those whose dirty hands have acquired disease bacteria, or if the foods are allowed to stand exposed to dust and dirt, they collect germs. If the food is afterward thoroughly cooked, the germs are generally killed. If, however, as in the case of bread, fruit, and some vegetables, no cooking is done before the foods are eaten, the foods may often carry disease.

Milk is particularly liable to be infected with disease germs because they readily grow in it and increase rapidly. Many epidemics of typhoid fever, scarlet fever, diphtheria, and other germ diseases have been directly traced to polluted milk. Either the milk came directly from dairies where these diseases existed, or had been put into bottles taken from infected homes and not afterward sterilized.

The older such milk becomes the greater is the danger of using it since bacteria multiply in it with such tremendous rapidity.

Infants are particularly liable to contract diseases from impure milk because this is their main diet. Statistics show that a large percentage of infant deaths are caused by in-



MAKING SURE OF CLEAN MILK

All the cows in a well-conducted dairy are carefully cleaned before milking time in order to avoid contamination of the milk.

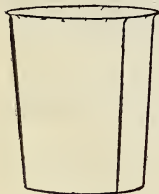
fectured milk. If milk is scalded the germs are killed, but scalding makes milk less palatable and less digestible. When milk is thoroughly heated to a temperature of from 145° to 160° F. for fifteen or twenty minutes and then speedily cooled, the disease germs are killed but the milk itself is not made less digestible nor is its taste affected. This is called *pasteurization*. The pasteurized milk should be covered with absorbent cotton, and kept in a refrigerator so that fresh germs cannot infect it. Pasteurized milk

is the only safe milk to use unless it is absolutely known that great care has been taken to keep the milk at all times clean and cold enough to be safe from infection. Certain cities require that all milk sold shall either come from healthy cows in dairies of "certified" cleanliness or else shall be pasteurized. Refrigerators and places where milk and food are kept must be washed and thoroughly scalded with hot water frequently if they are to be kept free from bacterial infection.

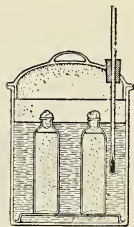
Oral Reports.—Report a practical method for pasteurizing milk in the home. "Milk and Its Uses in the Home," Farmers' Bulletin 1359, 5¢.

Report on the proper care of a refrigerator. "Care of Food in the Home," Farmers' Bulletin 1374, 5¢.

Dangers from Infected Water.—Water is also a dangerous carrier of bacteria. Water from deep artesian wells is usually safe, but streams that flow over the surface of the ground continually have washed into them materials which contain germs. Unless great care is taken to keep surface water out of springs or wells and to keep the drainage from stables and out-buildings from seeping into them, they become dangerous as sources of water supply. Impure water is an ever-active source of disease and one that can not be too carefully watched. (Page 233.)



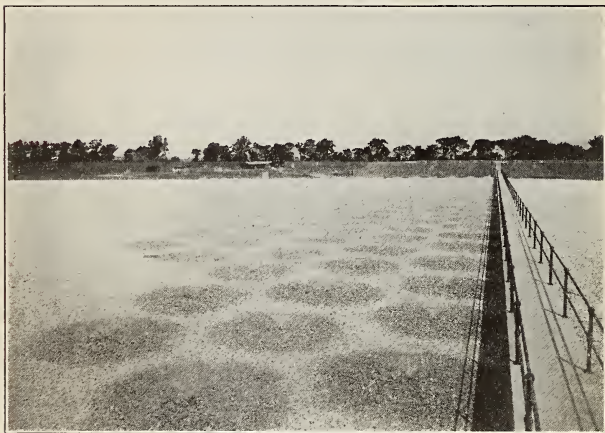
PAPER DRINKING CUP



A SIMPLE
PASTEURIZING
OUTFIT

Many of our large cities have in recent years expended vast sums of money upon their water supplies in order that citizens may be protected as far as possible from disease. The drainage canal which Chicago built at great expense to divert its sewage from Lake Michigan greatly lowered the death rate from typhoid fever in that city. Further

decrease in typhoid and intestinal diseases in Chicago and in other large cities is due to the fact that a large part of the milk which is now used there is pasteurized. Care concerning these two most important supplies, water and milk, has greatly decreased the death rate in many American cities during the present century. It is estimated that the actual money loss each year in the United States be-



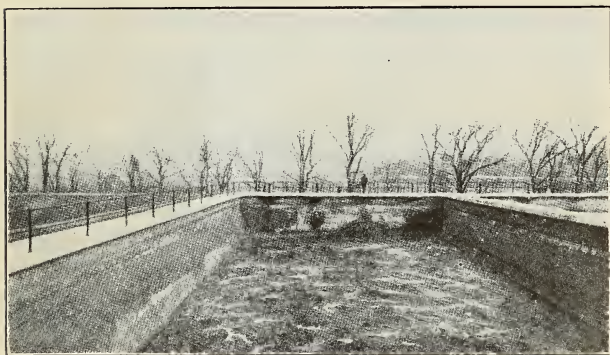
Courtesy of Department of Public Works, Columbus, Ohio
SEWAGE DISPOSAL BED, LIQUIDS

cause of the ravages of preventable diseases is between one and two billion dollars.

When there is any doubt about the purity of water it should be boiled for sixteen minutes. This will kill the dangerous bacteria. Boiling drives off the air and makes water taste flat. To restore the sparkle, pour the water rapidly from one vessel to another several times. This aerates the water. A few drops of lemon juice add surprisingly to the palatability of boiled water.

Ordinary house filters are useless and often worse than useless, as they simply become breeding places for bacteria. They may make the water look clearer but they do not destroy the bacteria; and it is the bacteria, not the solid matter, that constitute the real danger.

Bacteria can live and grow in such minute cracks that to use dishes washed in impure water is about as dangerous as to drink the water. All public towels and drinking cups should be abolished. Experiments have shown that even



Courtesy of Department of Public Works, Columbus, Ohio
SEWAGE DISPOSAL BED, SOLIDS

drinking fountains unless most carefully constructed are liable to retain in the pipes germs left by other users. The use of the individual cup is the one safe method for drinking.

Sewage Disposal.—The proper disposal of human waste is a vital problem. Exposure to wind and flies allows the germs in it to be spread about. The waste must therefore be disposed of in some way or disinfected. On the farm or in small towns where running water can be supplied, septic

tanks answer the purpose. It has been proved that cess-pools are always a possible source of danger. In cities, however, most complicated systems of sewage disposal must be employed. In the most healthful cities the sewage is gathered from all parts of the city by means of water flowing in underground sewers. In seaboard cities the sewers usually empty into the sea and the tides and currents dispose of all sewage.

Cities upon large rivers frequently empty their sewage into the rivers, but this pollutes the water far downstream. A very much better way than this has of late years been devised and is being used by many inland cities.

Sewage disposal plants for cities and septic tanks for rural homes are alike in that both take advantage of the work of the various kinds of bacteria of decay. The sewage is first run into a settling tank where the solid wastes settle to the bottom. Certain kinds of bacteria immediately set about changing these solids to liquids and gases. But even in the most efficient plants, there is a gradual accumulation of solids that do not liquefy. This accumulation, called *sludge*, is removed from time to time and used as fertilizer.

In the most modern plants, the liquids pass on from the settling tank and are sprayed on beds of sand and gravel. These liquids still hold partly decayed wastes in solution. As the liquids slowly trickle through the filter beds, other kinds of bacteria complete the work of decomposing the organic matter.

SUMMARY

Protoplasm is the only living material. It exists in minute cells in all living things. It has the power of growth, the power to manufacture materials needed by the living organism, and the power of repairing wounded or

worn-out tissue. In short, the cells containing protoplasm are the seat of every activity of every living thing.

The plants that have chlorophyll and that with its aid manufacture their own food are called independent plants. The roots and leaves of independent plants have been discussed in previous chapters. Stems, flowers, and seeds of independent plants are discussed in this chapter.

The work of the stem is to support the leaves, to conduct food elements from the roots to the leaves, to convey the manufactured foods from the leaves down toward the roots, and to store foods for future use of the plant. The age of a tree may be ascertained by counting the rings in a cross section of the trunk or stem. Many stumps of California redwoods and of the cedars of Lebanon have been found that are over two thousand years old. Softwoods come from the trees of the pine family. Hardwoods are from the broad-leaved trees that lose their leaves in autumn.

The flower of the independent plant consists in the main of calyx, corolla, stamen, and pistils. The chief function of the flower is to produce seeds from which succeeding generations of plants grow. In the fertilization of flowers, winds and insects play a very important part. A seed contains the embryo plant and sufficient food to support its growth until the embryo is equipped with its own roots and leaves.

All food plants once grew wild. Plants battle with each other for existence. Man battles in behalf of certain chosen plants. At times his efforts in behalf of certain plants have resulted in a great deal of trouble for himself.

In recent years much has been done for the improvement of plants. The three avenues of plant improvement are the flower, the seed, and the stem.

Plants that are unable to manufacture their own food find their food either in the living or in the dead parts of

plants or animals. These are called dependent plants. Among them are mildew; smut on corn, oats, and barley; molds, yeast; bacteria that change food; and the bacteria of disease.

Foods may be preserved from the bacteria that "spoil" them by drying, freezing and smoking; by means of salt, sugar, vinegar, and spices; or by boiling and sealing in sterilized cans.

Prevention of the spread of bacterial disease is aided by quarantine of the sick, care in the handling of foods, guarding of the water supply from contamination, and by careful disposal of sewage.

QUESTIONS

What is the only living material? What is it able to do for the living organism?

What is an independent plant?

What are the main services the stem performs for the plant? What two great types of stems are there?

How can the age of a hardwood tree be ascertained? Where are the best known trees found? What is sapwood? Heartwood? What are meant by the terms "hardwoods" and "softwoods"?

How does a plant reproduce its own kind? What service in this connection do winds and insects render?

What are some of the ways in which seeds are disposed? How is the embryo plant kept alive underground until it develops roots and leaves?

Why does man interfere in the natural struggle of plants for existence?

What are some of the ways in which the war against weeds may be wisely conducted?

What is meant by "the balance of life"?

What other reasons are there besides sentimental reasons for preserving wild flowers?

What are the three avenues of plant improvement?

How is seed tested? What are the advantages of seed testing?

Tell how plant breeders set about originating better seed. What are the advantages of grafting and budding?

Tell something of the great work of Luther Burbank.

What is a dependent plant? Mention examples.

What are molds? Yeasts? Bacteria? Spores?

What are some of the desirable as well as undesirable changes in food that are brought about by bacteria?

How are various kinds of food preserved against the action of bacteria?

What are some of the most practical ways of preventing the spread of bacterial diseases?

How is milk guarded against infection?

What are the dangers from impure water?

What is the most satisfactory way of disposing of sewage in rural districts? In cities?

CHAPTER XVI

ANIMAL LIFE

*For He, who gave this vast machine to roll,
Breathed Life in them, in us a Reasoning Soul.*

—Translation from Juvenal.

Animals do not take their energy directly from the sunlight, but indirectly from the latent energy stored up in the foods prepared by green plants. These foods may be eaten as stored by the plants, or they may have passed through the medium of other plants and animals. The energy thus stored up is liberated by combining the carbon with oxygen. Carbon dioxide is freed.

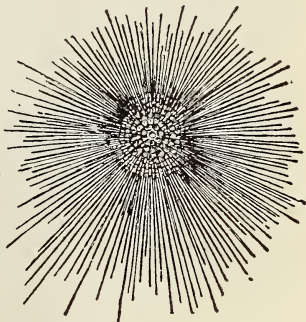
The green plants use this carbon dioxide again and, by the aid of the sun's energy, free the oxygen and store up the carbon. Thus the cycle goes on, over and over, the plants freeing oxygen and taking up carbon dioxide, and the animals freeing carbon dioxide and taking up oxygen. The cells of plants which feed upon the food prepared by the chlorophyll of the leaves use oxygen and give out carbon dioxide just as the animal cells do; so also do other plants to some extent.

Classification of Animals.—For convenience of study the animal kingdom has been divided into two great classes—the *invertebrates* (without backbone) and the *vertebrates* (with backbone). The invertebrate is the much more numerous class as it contains the worms, shellfish, insects, and those almost countless forms of animal life which have no internal bony skeleton and backbone. The higher

animals, like fishes, amphibia, reptiles, birds, and mammals, belong to the class of vertebrates. Man himself is the highest of the vertebrates, and his structure will be studied later.

I. LOWEST FORMS OF LIFE

Protozoa.—The very lowest forms of animal life, the *protozoa*, are single-celled animals. In some species they are very difficult to distinguish from plants of the lowest orders. They are microscopic in size and most of them live in water. Some of these tiny protozoa living in the sea are covered by an extremely thin shell of lime. When they die, their shells sink to the bottom of the sea. So rapidly do these animals multiply that their minute shells have made thick layers of chalk like the famous chalk cliffs of the south of England (page 308).



GLOBIGERINA (Greatly Magnified)

The shells of these single-celled animals cover much of the ocean floor. They formed in past ages the limestone beds and chalk cliffs that have since been raised above the level of the sea.

Our chief interest in protozoa in the present study is that certain of them are the cause of several kinds of disease which can readily be prevented with proper care. Malaria and the terrible African disease called *sleeping sickness*, and probably yellow fever, are caused by these little animals. We shall study them more fully later in connection with insects.

Worms.—Another class of invertebrates is the *worms*. If an earthworm is examined, it will be seen that the

body is made up of segments or rings, and that it moves by successively shortening and elongating its body. Extending through the middle of the body is an alimentary canal consisting of a mouth, gizzard for grinding food, stomach and intestines.



AMOEBA DIVIDING

The amoeba is a one-celled animal which increases by dividing, as does a bacterium.

Near the head is a little nerve center. The whole animal may be regarded as built up by the joining of a number of essentially similar segments. A more minute examination will show that these segments have been materially modified in some portions of the animal, but they have not been in any respect organized, as have the different parts of higher animals. This simple animal is an untiring worker in preparing and fertilizing soil for plants, and thus is a most efficient helper to man.

II. THE WORK OF INSECTS

Insects.—Assignment.—Procure a grasshopper or honey-bee, as a type insect, and inclose it in a small, glass-covered box. Into how



EARTHWORM

A great helper to the farmer.

many parts is the body divided? Describe these parts. To which part are the legs attached? The wings? How many legs are there? How many wings? Notice the largest part into which the body is divided. Notice the eyes and the feelers, or *antennæ*, on the head. Write a short description of the general characteristics of the insect's body.

The *insects* are among the most important of animals. This class contains more than half the known animal



ICHNEUMON FLIES

Friendly insects. They lay their eggs in harmful caterpillars. The eggs hatch and the larvae kill the caterpillars.

species. They are spread widely over all parts of the earth. They include butterflies, bees, ants, flies, mosquitoes, grasshoppers, gnats, beetles, and tens of thousands of other forms of six-legged life.

In our examination of a typical insect, we find that the body of the insect is divided into three parts. These parts are called head, thorax, and abdomen. The eyes and the feelers, or *antennæ*, are on the head. The mouth is a very complex organ, fitted both for biting and for sucking. The six legs and four wings are on the thorax. Insects have no lungs. They breathe by means of tubes on each side of the abdomen. These tubes branch and the



Courtesy U. S. Bureau of Entomology

ARMY WORM MOTH

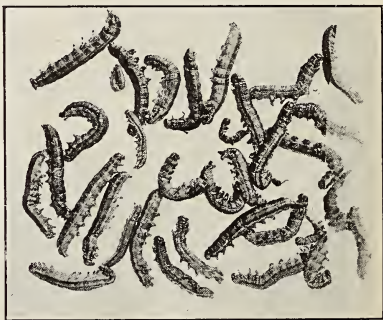
The army worm which sometimes attacks crops in tremendous numbers is the larval form of this moth.

of millions of dollars' worth of crops and trees. It has been estimated that in the United States insects destroy every year crops and trees which have a value of \$50,000,000, to say nothing of the countless losses due to diseases spread by flies and mosquitoes. (Page 466.) Not many years ago grasshoppers nearly devastated several of the middle western states.

Some of our plant pests are so tiny that the inexperienced gardener overlooks them. Plant lice, so com-

branches divide again and again until they convey oxygen to all the cells of the insect organism.

Friendly and Unfriendly Insects.—Both good and bad insects abound. Economically, they furnish millions upon millions of dollars' worth of produce every year and on the other hand destroy hundreds



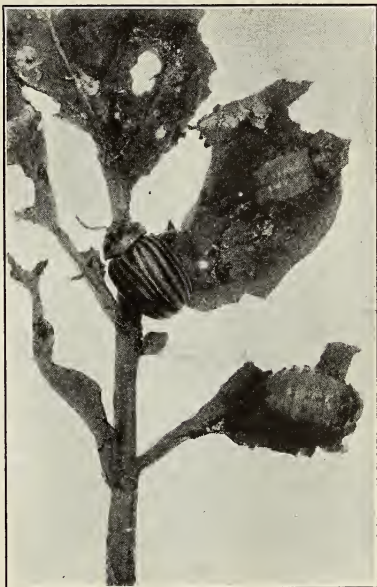
Courtesy U. S. Bureau of Entomology

DEAD ARMY WORMS

Army worms do their chief damage in the grain areas of the central Mississippi Valley. It has been estimated that they do as much as fifteen million dollars damage a year.

mon to house plants and garden plants, destroy many plants by sucking their juices. The San Jose scale, an insect no bigger than a pinhead, is a dangerous enemy of fruit trees and many shade trees.

Insects develop from eggs and go through two stages, the *larva* and the *pupa*, before they reach the adult stage. The grub or caterpillar that hatches from the egg is called the larva. It is in this larva stage that so many insects do their great damage. The boll-weevil, for example, lays its eggs in the buds and bolls of the cotton plant. The larvae feed on the buds and bolls, and thus destroy the cotton



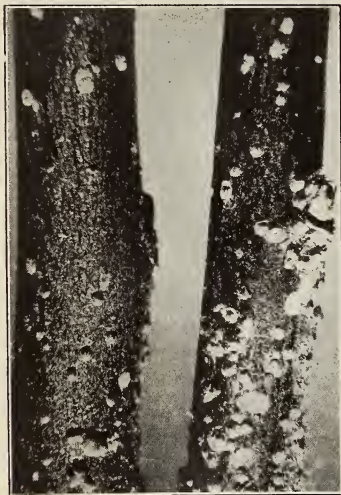
Courtesy U. S. Bureau of Entomology

POTATO BUG AT WORK ON POTATO PLANT

crop. The larvae of the gipsy-moth, the brown-tail moth, and the tussock moth are very destructive to foliage. The codling-moth lays her eggs in the calyx of the apple blossom. The grub that hatches eats its way into the tiny apple, develops there, and eats its way out again.

The potato bug, or Colorado beetle, was formerly confined to the eastern slope of the Rocky Mountains, where it lived on wild plants that belong to the potato family.

As soon as settlers introduced the cultivated potato into Colorado, the beetle turned its attention to this new plant. Within fifteen years it had spread from patch to patch until it had reached the Atlantic coast. It is now found in almost every country where potatoes are raised,



THE SAN JOSE SCALE

This pest has destroyed thousands of orchards.

having only recently made its appearance in Germany. The Colorado beetle lays her eggs on the under side of the leaf or the stem of the potato plant. As the larvae hatch out, they immediately attack the foliage of the potato plant, with disastrous results unless they are checked.

Fortunately, there are friendly insects, birds, and other forms of animal life that help us fight our battles against the insect pests. The dragon-fly, or "devil's darning needle," eats mosquitoes and flies.

The ichneumon fly lays its eggs in the bodies or larvae of destructive insects, such as the tussock moth and the army worm. The Chinese ladybird beetle, commonly called the "ladybug," feeds on scale, plant lice, and eggs of injurious insects. Wasps are destroyers of our insect enemies. Spiders are not true insects, but they do great service in destroying harmful insect life. All these friendly forms of life deserve protection; because they help to keep the world from being overrun by insect pests.

Written Reports.—Let each of several students make a study of some insect of your section that is an enemy of farm crops, orchards, shade trees, flower or vegetable gardens. How does this insect do its damage and how is it controlled or destroyed? You can get much information from farmers, gardeners, orchardists, nurserymen, seed-stores, etc. If you wish to make further study of any insect problem, write the Superintendent of Documents, Washington, D. C., for a list of publications of the Bureau of Entomology. From this list you will be able to choose, and obtain for a few cents, a pamphlet on almost any insect problem of any section of the country.

The following are two very useful bulletins: "How to Detect Outbreaks of Insects and Save the Crops," Farmers' Bulletin 835. "Control of Diseases and Insect Enemies of the Home Vegetable Garden," Farmers' Bulletin 856.

Productive Insects.—

The most productive insects are the silkworms and the bees. Without the silkworm there would be no silk produced, and without the bee, no honey. These two products each year run into hundreds of millions of dollars. We have already seen that bees and other insects are needed also for the fertilization of flowers.



Courtesy U. S. Bureau of Entomology

PUPAE OF CHINESE LADYBIRD BEETLE

A friendly insect that destroys unfriendly insects. Notice how the spines protect the helpless pupae from attack.

Among the most interesting of the insects and perhaps, everything considered, the most valuable, is the *honey-bee*. This is the great flower fertilizer; it would fertilize about all the plants man really needs except the red clover. In the United States alone there is produced by it about twenty-five million dollars' worth of honey and wax each year.

The Honey-bee.—Honey-bees, ants, bumble-bees, and social wasps are known as social insects because they live



BEEHIVES

Hundreds of dollars' worth of honey are produced here each year

in well-ordered colonies. In the honey-bee colony there are three kinds of bees, the male bees, or drones, the workers, and the queen or female bee.

The workers do all the work of the hive. They gather nectar from the bases of flowers and carry it home in a sac that corresponds somewhat to the crop of a chicken. While in this sac, the nectar undergoes changes we do not

understand; for when it is deposited in the comb, it is no longer flower nectar—it is honey.

It is in seeking for nectar that the bee visits so many flowers and scrapes the pollen on to the different parts of its body to be borne away to fertilize other flowers which it enters. Pollen is also used by the bee as food for its young. The hind legs of each working bee are so shaped and fringed with hairs as to enable the bee to carry loads of pollen back to the hive.

The most astonishing thing about a beehive is the division of labor among the workers and the faithful, orderly performance of duties. Certain workers are stationed at the entrance to ventilate the hive by the fanning of their wings. Others are entrusted with the duties of hive cleaning, for bees are scrupulously clean. Still others manufacture the wax and build the comb.

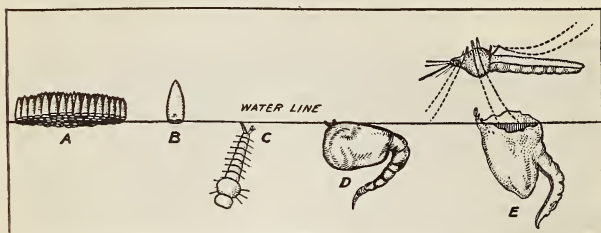
The wax is secreted from glands in the abdomens of the workers and with this the bees build the comb. Each cell is hexagonal in cross section and the comb is so constructed that the least possible amount of wax will inclose the greatest possible amount of honey.

It is the duty of certain workers to act as nurses for the helpless grubs. They feed the grubs on rich food formed in their own stomachs, as well as on pollen mixed with honey. The grubs are the first stage in the development of the bee from the egg. The queen lays all the eggs, sometimes as many as a million. There is but one queen in each swarm. Whenever another queen is ready to be hatched, the old queen takes about half the colony and goes off to form another swarm.

Such an interesting animal and so exceedingly useful is the bee that hundreds of books have been written about it, more than about any other domestic animal. Some of these should be read for further information concerning this most instructive animal.

Oral Reports.—"The Story of the Silkworm" and "Life in an Ant-hill" make intensely interesting subjects for oral reports. See Appendix for references.

Insects That Spread Disease.—Certain low forms of animal life, the protozoa, have already been mentioned as disease producers. Unlike bacteria, the protozoa do not cause disease by passing directly from one person to another. Instead, they need to live in some insect between whiles. In malaria and yellow fever the insect in which



STAGES IN THE LIFE OF A MOSQUITO

A, "raft" of eggs; B, a single egg; C, larva; D, pupa; E, adult mosquito, emerging.

they live is the mosquito, and in the sleeping sickness they live in a fly called the *tsetse*. If a mosquito of the right species bites a person afflicted with malaria or yellow fever, some of these little animals, the protozoa, are sucked up with the blood and enter the mosquito. They grow in its body, undergoing several changes, until the animal germs are ready to be injected into their victim, when they pass into the salivary glands of the mosquito. In biting, the mosquito always injects a little saliva into the wound and with this go the germs. These enter the blood, multiply rapidly, and cause the disease.

If mosquitoes can be kept from biting people who have these diseases or if infected mosquitoes can be kept from biting other people, such diseases will not spread. The

best way to keep mosquitoes from biting is to exterminate them. Since mosquitoes breed in stagnant water, all old ditches or small pools where water accumulates should be emptied and drained. Larger stagnant pools should be drained or have a film of kerosene spread over their surface by frequently pouring a little of the oil on the water. This will keep the mosquitoes from breeding and prevent the diseases.



HOUSE FLY (Magnified)

The Texas fever, which has caused such great financial losses to the cattlemen of the United States, is caused by a protozoan injected into the cattle by the bite of a tick.

Bubonic plague, the "Black Death" that swept Europe during the Middle Ages, is spread by the bite of a flea that lives on plague-infested rats. Hundreds of thousands of dollars have been spent by the Government in killing rats in some of the ports of the United States where the plague has succeeded in landing. Many seaports are now rat-proofing their wharves in an effort to exterminate these pests. The cables holding ships to the docks are often passed



BACTERIA COLONIES

These were developed from the tracks of a fly on a gelatine plate.

through holes in the centers of metal sheets in order to prevent rats from entering a ship by walking along the cables. Sailors have learned that if the rats are kept out, the plague is kept out.

Flies.—The words *fly* and *filth* are almost synonymous. Flies breed in any kind of decaying vegetable or animal matter. The eggs hatch in about a day and the little white maggots after absorbing filth for about ten days change into adult flies with their hairy bodies and sticky feet, especially adapted for carrying all kinds of germs and for spreading them over everything they touch. The fly delights to feed on all kinds of foul or diseased objects, and the waste it deposits is often full of dangerous germs.

“Swat the fly” is indeed a proper slogan. But a still better plan would be to destroy all filth or to dispose of it so as to prevent flies from breeding. Flies never travel far and their presence indicates filth in the neighborhood. If manure and other decaying matter is kept in covered pits until it is used for fertilizing, and if garbage cans are kept covered, much more will be done to exterminate the fly than by swatting. Houses should be carefully screened and all food kept covered from these carriers of disease, but along with all precautions to avoid the fly must go consistent efforts to exterminate the fly.

Oral Reports.—Make a report on the development of the mosquito from the egg to the full-grown insect.

How can mosquitoes be destroyed in the larva stage?

What can be done to prevent rain barrels, water-tanks, and cisterns from serving as breeding places for mosquitoes?

Where pools must be kept clean for the watering of stock, what can be done to combat the mosquitoes?

The following Farmers' Bulletins deal with the subject of mosquitoes.

“Some Facts about Malaria,” Farmers' Bulletin No. 450.

“The Yellow Fever Mosquito,” Farmers' Bulletin No. 547.

“Remedies and Preventives against Mosquitoes,” Farmers' Bulletin No. 444.

Voluntary Project.—If your community or neighborhood is troubled with mosquitoes, plan a campaign for exterminating the pest. Don't forget the cans, bottles, etc., on rubbish heaps.

Voluntary Project.—With the aid of Farmers' Bulletin 1408, “The

Housefly and How to Suppress It," lay out a campaign for making your community flyless.

Try to interest some civic organization in your project. Fighting the fly is primarily a community project. You can do something and should do everything in your power on your own premises, but coöperation is necessary if the fly is to be conquered. The community must be educated to the menace of the fly before anything worth while can be accomplished, and this often requires the combined effort of local newspapers and civic clubs. Some day people will wonder that we tolerated such a menace, exactly as we wonder at the unsanitary living conditions common centuries ago.

III. HIGHER FORMS OF LIFE

Vertebrates.—Assignment.—If possible, secure the skeleton of some vertebrate animal, preferably man. Notice how the bones are fitted to each other and how the joints are arranged to allow movement. Observe how carefully the brain and the spinal cord are protected, and also the thorax, which contains the heart and lungs. If a human skeleton is procured, notice the curving of the spine which enables the body to stand erect.

We have just studied briefly some of the invertebrates most closely related to the welfare or injury of man. Man himself belongs to the other great class, vertebrates. The higher animals which furnish him with the greater part of his animal food also belong to this class. Although there are great variations in the structure of vertebrate animals, yet they are alike in having a backbone and an inner supporting skeleton.

The bony *skeleton* in the higher forms of animal life consists of a vertebral column, skull, ribs, and appendages. The main skeleton protects the most delicate organs and acts as a support for the attachment of the muscles. The appendages, like the legs and arms in man, are jointed to the central part of the skeleton, and it is the action of the muscles in moving these about the joints that makes movement from place to place possible.

In the skull is situated the great nerve center of the

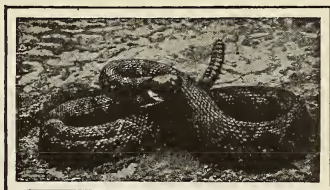
animal, the *brain*, and from this through the vertebral column passes the great nerve distributor, the *spinal cord*. From the brain, *nerves* are sent to all the muscles of the body, to the skin and to those organs, like the eye and the ear, which transmit to the brain impressions received from without the body. These nerves give the stimuli which cause the muscles to thicken, or contract. In fact, all the voluntary movements of animals are controlled from the brain, as the movements of trains on a railroad are controlled from the dispatcher's office.

Lowest Forms of Vertebrates.—Fishes are the lowest order of vertebrates. Probably the most interesting thing about them is their wonderful adaptation to life in the water. They are equipped with air-bladders, which, some scientists believe, enable the fishes to make their bodies heavier or lighter as they dive or rise toward the surface. The bodies of fishes taper at both ends so as to offer the least resistance to water in swimming. Their limbs take the form of fins.

Fishes must have oxygen, but they do not need so much as land animals must have. What oxygen they need they obtain, through gills rather than lungs, from air that is dissolved in water (page 226). A fish takes water into the mouth at regular intervals and forces it back through the gill openings. Here oxygen in solution is absorbed by the blood passing through the gills.

The chief interest of the ordinary man in fishes lies in his use of them for food. The most popular of the food-fishes, such as the salmon, the whitefish, and the brook trout, would probably become extinct if it were not for protection afforded them by federal and state laws. To give further protection to these old favorites, the Bureau of Fisheries of the United States Department of Commerce is trying to educate people to widen their demands

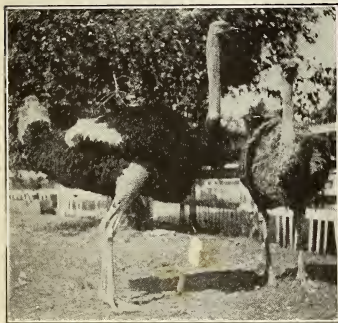
for food-fish. The grayfish, the whiting, the carp, and even the shark are excellent food-fishes and they exist in great numbers. Only ignorance of their food-value keeps people from furnishing a market for them. The grayfish and the whiting, however, are beginning to come into wider demand.



RATTLESNAKE COILED READY TO SPRING

The color of these reptiles makes them hardly distinguishable from the surrounding desert.

The form of vertebrates next higher than the fishes are the animals that live part of the time in water, and part of the time out of it—frogs and toads, for example. Next above these come snakes, lizards, crocodiles, and alligators. It is surprising how many of these forms of life that we ordinarily despise are deserving of protection in the interest of maintaining the balance of life.



OSTRICHES

The largest of all birds.

Birds.—Next above the reptiles are the birds. The higher forms of bird life show remarkable adaptations for flying. Their bones are thin and hollow.

They have air cavities in the thorax and abdomen. The forelimbs of most birds are adapted to flying by a covering of strong feathers, and the tail serves as a rudder for steering the bird's course through the air. The "wishbone" is

shaped like the keel of a boat and furnishes anchorage for the strong muscles of flight.

So important is the work of birds in aid of man that it is doubtful whether he could continue to exist without them. It is true that some birds seem to thrive at the



Courtesy U. S. Bureau of Biological Survey

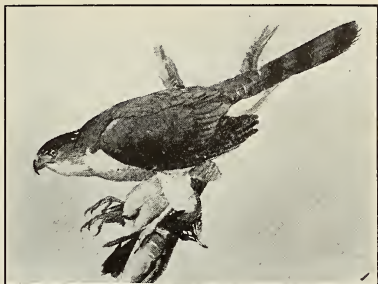
ROBIN ON NEST

expense of man's crops; but in the vast majority of cases, the genuine service birds render far outweighs the damage they do. They eat the seeds of noxious weeds, they feed on harmful insects and their larvae, and they surpass all other animals in effective warfare on rats and mice.

Nobody ever seems to doubt that the robin, the wren, the oriole, the larks, the bobwhite, and the cardinal are allies of man in the war on vermin. But the crow, the owls, the hawks, and some other birds have been looked

on by many people as the outlaws of the bird community.

To find out whether it is just to condemn these and other birds, the United States Bureau of Biological Survey has made careful study of the problem. In the course of their investigations, they have examined the contents of the stomachs of thousands of birds that are under suspicion. Their conclusions are that very few birds deserve to be sentenced to extermination.



Courtesy U. S. Bureau of Biological Survey

COOPER HAWK

The crow has been accused of robbing grain fields, of killing useful birds and of sucking their eggs. The con-



Courtesy U. S. Bureau of Biological Survey

BARN OWL

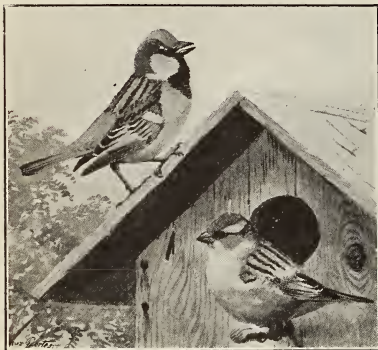
tents of thousands of crow stomachs were examined to find out whether the bird was justly accused. The evidence showed that an occasional bird or bird egg served as food. But for every grain of wheat or corn eaten the stomachs contained a cut-

worm or some other injurious insect.

Of fifty varieties of hawks, only three—the Cooper hawk, the sharp-shinned hawk, and the Canadian gos-

hawk—are classed as robbers of the chicken-yard. The others *occasionally* kill chickens, but spend most of their time reducing the numbers of rats, mice, gophers, etc. Of all the owls, the horned owl is the only outlaw. All the others subsist chiefly on grasshoppers, caterpillars, frogs, mice, and rats. The barn owl lives almost exclusively on

mice and rats. One of them about a farmstead is said to be as useful as an army of sixty cats.



Courtesy U. S. Bureau of Biological Survey

ENGLISH SPARROWS

The English Sparrow.—Among the very few birds that seem to be utterly condemned is the English sparrow. It was brought to America about three-quarters of a century ago. Like

the cactus plant in Australia, this bird in America has taken on new vigor and has become a pest. It damages wheat in all stages of growth from the sprout to the standing grain. It destroys fruits, buds, and flowers. It nips the young sprouts of the vegetable garden. It makes war on wrens, martins, bluebirds, and swallows. It destroys their eggs and their young, and drives the old birds from their nests. It is noisy, dirty, and slovenly. Nobody has risen to say a kind word for it. The Biological Survey approves of the verdict of extermination for this sparrow.

Voluntary Projects.—To study bird life.—1. Learn to distinguish at least two kinds of birds you have never known before. 2. Build a bird-house or bird-houses, and encourage birds to seek your prem-

ises. 3. Find out whether your prejudice against some particular kind of bird is justifiable. For help in carrying out these projects, consult the Farmers' Bulletins and books listed in the Appendix.

Mammals.—The highest order of vertebrates is distinguished mainly by the fact that their young are nourished from birth with milk secreted by the milk-glands of



Courtesy U. S. Bureau of Biological Survey

HALF-GROWN MOUNTAIN LIONS

the mother. This group is called *mammals*, from the Latin word *mammæ*; meaning milk-glands. To this class belong man and the "beasts of the field." Man's herds and flocks, the horse, the cat, the dog, and all of the four-footed wild animals are mammals.

The hoofed mammals, including the cow, the horse, the sheep, etc., are the most useful group to man. The *carnivorous* (flesh-eating) mammals include man's best friend, the dog, and his most powerful enemies, the lion, the tiger, and the wolf.

Man's War against Predatory Mammals.—The farmers' and cattlemen's war in our western states against the coyote, the timber wolf, the mountain lion, and the wildcat is approved by the United States Biological Survey. Domestic animals and deer form the main diet of the powerful wild flesh-eaters. Dr. Bell of the Biological Survey says that the average destruction that may be



Courtesy U. S. Bureau of Biological Survey
GRAY WOLF

charged against each wildcat and coyote amounts to about \$50 a year, while each wolf and mountain lion is responsible for about \$1000 worth of damage.

Professor Anthony of the American Museum of Natural History opposes this wholesale

destruction of the wild flesh-eaters, on the ground that it tends to disturb the balance of life unfavorably. He holds that these predatory animals do great service in keeping down the number of harmful mammals that belong to the gnawing group, rats, mice, rabbits, etc. It is true that as carnivorous wild animals have disappeared, the rabbit has increased in some sections to the point of being a pest.

But the experts of the Biological Survey reply that even where predatory animals still exist, they no longer render service in keeping down the numbers of rats, mice, and rabbits. In the past five years thousands of predatory animals have been killed and the contents of their stomachs examined. These examinations furnish evidence

that the predatory mammals confine themselves almost wholly to a diet of domestic animals.

At any rate it would be difficult to persuade the cattleman that the services of these animals that prey on his herds outweigh the damage they do. And so the mountain lion, the timber wolf, the coyote, and the bobcat are



CALIFORNIA RABBIT DRIVE

In some localities rabbits become such a pest that the inhabitants turn out in a body, drive them into inclosures, and kill them.

probably doomed. Wherever man goes he fights to preserve his flocks and herds from their enemies. It is probable that within another century the big game animals of Africa will have disappeared. The marvelous new cure for sleeping sickness bids fair to make the interior of that continent a safe home for the white man. When he begins to take possession with his horses and cattle and sheep, he will open his war to the death against the lion, the tiger, and all the other predatory animals of the Dark Continent.



A HERD OF AMERICAN BISON

This animal was about to become extinct. In recent years the United States Government has protected the bison and its numbers have greatly increased.

The Rat, One of the Worst Enemies of Man.—Among all mammals, the worst pest known to man is the rat. We have seen that it is responsible for the spread of bubonic plague. Its unclean habits undoubtedly cause it



Courtesy U. S. Bureau of Biological Survey

COYOTE

"Wild dog of the desert."

to spread other diseases. This alone would be sufficient reason for condemning the rat to death.

But there are other counts against it. It is the most persistent enemy of the farmer. It destroys seedlings, standing grain, grain in the shock, grain in the barn, in

the warehouse, and in the mill. It destroys poultry, useful birds, their eggs and their young. It causes fires by gnawing the insulation from electric wires. It destroys merchandise stored in warehouses, attics, and basements. The Biological Survey estimates that the rat alone is responsible for the destruction of more than \$200,000,000 worth of property a year in the United States.

Written Report.—Report on the most effective ways of making war on the rat. Individual war against rats either on city premises or on a farm may be made very effective, but in cities or villages, only united effort can achieve permanent results. Farmers' Bulletin 896 and Bulletin No. 33 of the Biological Survey offer a wide range of information and advice.

SUMMARY

Animals take their energy not directly from sunlight, but indirectly from the latent energy stored up in the foods prepared by green plants. When these foods are oxidized in the bodies of animals they produce energy and carbon dioxide is freed. The green plants themselves use the carbon dioxide again and by the aid of the sun's energy store up the carbon and free oxygen for the use of animals. Thus the cycle goes on.

For the convenience of study, the animal kingdom has been divided into two great classes—invertebrates (without backbone) and vertebrates (with backbone). The invertebrate is the much more numerous class as it contains the worms, shellfish, insects, and those almost countless forms of animal life which have no internal bony skeleton and backbone. Man himself is the highest form of vertebrate.

The very lowest forms of animal life, the protozoa, are single-celled animals. Among the lowest forms of many-celled invertebrates are the worms. Insects are among the most important of the invertebrates. This class con-

tains more than half of the known animal species. Many of them do so much harm to the forms of life that are useful to man that we look upon them as unfriendly. Some insects such as mosquitoes, fleas, ticks, and flies spread deadly diseases. Still other insects, like the honey-bee and the silkworm, produce hundreds of millions of dollars' worth of useful products each year. Insects like the Chinese ladybird beetle, wasps, and dragon flies fight man's battles against the unfriendly insects.

Although there are great variations in the structure of vertebrate animals, yet they are all alike in that they have a backbone and an inner supporting skeleton. Our present interest in the vertebrates lies in a study of them as they are related to the welfare or the injury of man.

Fishes are the lowest order of vertebrates. The vertebrates next higher in order than the fishes are animals that live part of the time in water and part of the time out of it—frogs and toads, for example. Next above these come snakes, lizards, crocodiles, and alligators. It is surprising how many of these forms of life that we ordinarily despise are deserving of protection in the interest of maintaining the balance of life.

Next above the reptiles are the birds. So important is the work of birds in aid of man that it is doubtful whether he could continue to exist without them. It is true that some of the birds seem to thrive at the expense of man's crops; but in the vast majority of cases, the genuine service birds render far outweighs the damage they do. Only a very few birds have been found to be so destructive that they are classed as outlaws. The worst of all these outlaws is the English sparrow and scientific authorities are agreed that it should be exterminated in America.

The highest order of vertebrates is distinguished mainly by the fact that their young are nourished from birth with milk secreted by the milk-glands of the mother. This

group is called mammals. To this class belong man and the "beasts of the field." Man's herds and flocks, the horse, the cat, the dog, and all of the four-footed wild animals are mammals. The hoofed mammals including the cow, the horse, the sheep, etc., are the most useful group to man. The carnivorous (flesh-eating) mammals include man's friend, the dog, and his powerful enemies, the lion, the tiger, and the wolf.

QUESTIONS

Explain the services that animals and plants render each other by way of the gases of the atmosphere. Why is this exchange of services called the "carbon cycle"?

What are the two great divisions of the animal kingdom?

What are the lowest forms of invertebrate life? What forms of life do insects include? Mention two unfriendly insects and tell how they do their damage. Mention two friendly insects and tell how they render their service. What are social insects?

Tell something of the honey-bee's work and life in the hive.

How do mosquitoes of a certain sort spread malaria? How is bubonic plague spread?

Why is the house fly a dangerous insect?

What are the lowest forms of vertebrates? Explain some of the interesting things about their structure.

What forms of vertebrates are there above the fishes in order but lower than the birds?

What are the great services rendered to man by birds? Why is the barn owl particularly valuable? Why has the English sparrow been condemned?

What are mammals?

CHAPTER XVII

HUMAN LIFE AND HEALTH

Accuse not Nature; she hath done her part; do thou but thine.—Milton.

Man is the highest form of animal creation. The practical purpose of the study of all science is to provide the most favorable conditions for human life. Increase and improvement of food supply, the betterment of the home with all its comforts, sanitation and hygiene in the community, the conveniences of modern travel and communication are among the practical outgrowths of science that bear on man's welfare. If betterment of man's estate is the first thing to be considered, no scientific study can be so important as that of health. For only the healthy individual can fully enjoy all the comforts and conveniences modern science provides, and can in turn make his contribution to the common good.

What conditions then are the most favorable for the life of man? How does the normal human body carry on its most important activities? And what are some of the essential things each man can do to keep his body fit? These are questions to be answered in this chapter.

Cell Life.—In both plant and animal life, the cell is the unit of life processes. We have seen that there are single-celled plants and single-celled animals. These single cells carry on all of the activities necessary for their own existence. The higher forms of plant and animal life are made up of many cells. But no one of these cells would be

capable of existing alone. In other words, each kind of cell has its own duty to perform for the cell community. Cells of a kind are grouped into tissues in order to accomplish the work of the cell on a large scale. If the cells of any tissue fail to work properly, the welfare of the entire cell community is affected.

It is impossible in a short time to become acquainted with all the different kinds of tissues of the human body, but it is well for us to know the work of the most important kinds and the conditions necessary for their healthy existence and uninterrupted performance of duty.

Work of the Cell Community.—First of all, the cells must have food. The body must move in order to obtain it, and these movements are the direct result of the work of cells in muscular tissues. But merely obtaining, preparing, chewing and swallowing food is not sufficient. Before it can be used by the cells of the body, it must be digested. This involves many changes of the food material, each of which is the work of some particular kind of tissue.

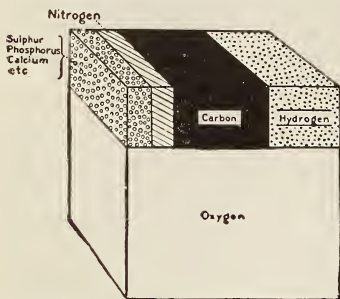
Every activity of the body requires energy, and so energy must be available. This is provided in the form of heat produced by oxidation. Oxygen must, therefore, be supplied to the cell community, and this is the particular work of certain tissues. But oxidation can occur only in the cells; and so there must be a system of transportation to carry digested food and oxygen to the cells and to carry away the wastes produced by oxidation. Millions of cells are therefore engaged solely in this work of transportation.

The foregoing are only a few of the most important kinds of cell labor. The body even maintains a system of defense against the germs of disease. Finally all these and other activities are controlled, and communication with the outside world is maintained by the brain and nerve system—the most wonderful tissues of all creation.

I. FOOD AND DIGESTION

Fundamental Foods.—The elements which enter into the structure of the human body, such as oxygen, hydrogen, nitrogen, carbon, etc., are comparatively few and are abundant in the world about us, either separately or in compounds. But with all of man's ingenuity, he has not

yet learned to manufacture these elements into compounds that will serve as food for the human body.



PROPORTIONS OF ELEMENTS IN COMPOSITION OF
LIVING THINGS

These food compounds may be supplied by either animals or plants. The original source of all animal and plant food, as we have seen, is in the chlorophyll manufactory of the leaf and green stem.

Here carbon, hydrogen, and oxygen are united by the aid of the sun into plant foods called *carbohydrates*. After this leaf food has been manufactured, it is simply modified for use by the plants and animals through which it passes.

Fats and *proteins* are two other kinds of foods that are manufactured in the bodies of both plants and animals, but the carbohydrates are the *original* material out of which the living organism, whether plant or animal, *first* produces fats and proteins.

Air, water, and salt are necessary to the processes of life, but they are not generally classed as foods. In leaves then and in leaves only are the lifeless (inorganic) substances of the earth combined into substances that will support life (organic compounds). The factories of nature are open

to man, and he knows fairly well what these factories produce. But how the compounds are produced either in the plant or in the animal and how the active material of the living cells called protoplasm does its work are mysteries to him. By careful study, however, man has learned a great deal as to foods necessary to the growth and health of the human body.

The Three Great Groups of Foods.—**Experiment 146.**—Place in different test tubes small amounts of (1) corn starch, (2) grape sugar, (3) scrapings from a raw potato, (4) flour, and (5) the white of an egg. Pour in a little water and shake thoroughly. Drop into each tube a few drops of the iodine solution prepared in Experiment 112.

Experiment 147.—(Teacher's Demonstration.)—Place in test tubes small quantities of (1) the white of a hard-boiled egg, (2) tallow or lard, (3) grape sugar, and (4) any other food which may be handy. Pour a little concentrated nitric acid into each tube and allow to stand for a minute. Be careful not to get the nitric acid on the clothes or hands. Pour the acid out into a slop jar and wash the substances with a little water. Pour off the wash water and pour on a little strong ammonia. If the substances turn a yellow or orange color, proteins are present. Which substances contain proteins?

Experiment 148.—(Teacher's Demonstration.)—(Gasoline vapor is very inflammable; be sure in this experiment that there is no flame in the room.) Place about a spoonful of (1) both the white and the yellow of an egg, (2) flax-seed meal, (3) yellow corn meal, (4) white flour, and (5) other foods it is desired to test in separate evaporating dishes or beakers near an open window. Pour on these more than enough gasoline to cover them, and stir thoroughly. Cover the evaporating dishes and allow to stand for ten or fifteen minutes. Pour the gasoline off into a beaker and set the beaker outside the window until the gasoline has evaporated. If there is anything left it must have been dissolved from the food. If a substance remains, place a drop of it on a piece of paper. Smell of it. Try to mix it with water. Rub it between the fingers. Try any other fat or oil test of which you can think.

Experiment 149.—(Teacher's Demonstration.)—In a place where there is a good draft so that odors will not penetrate the room, burn in an iron spoon over a Bunsen burner (1) small pieces of meat, (2)

a little condensed milk or milk powder, (3) part of an egg, and (4) any other food. Is there a residue left after burning? If so, this is mineral matter.

In the preceding experiments we have dealt with the three great groups of organic compounds, carbohydrates (starches and sugars), fats and oils, and proteins (foods containing nitrogen).



A BUNCH OF DATES

An excellent food for hot climates.

The foods that contain large percentages of carbohydrates are vegetables, fruits, and most cereals. The fats are most abundant in butter, cream, fat meats, nuts, chocolate, and vegetable oils such as olive and cottonseed oils. The common foods that are rich in proteins are lean meats, eggs, beans, peas, and certain cereals, especially oatmeal. Milk contains all three of these compounds in approximately the proportions needed by the body.

The Use of Each Food-Group.—The various kinds of food are used by the body (1) in growing new cells, (2) in repairing cells that have been used up or destroyed, (3) in providing energy to carry on the activities of the body and maintain its heat, or (4) in doing external work, such as moving the body itself from place to place or moving other bodies.

Much more food is used for energy (bodily warmth and

activity) than for growth or repair. All foods furnish energy when they are oxidized in the body. But the carbohydrates and fats are best adapted to this purpose.

Carbohydrates are made up wholly of carbon, hydrogen, and oxygen. When these compounds are oxidized in the cells, the carbon (C) unites with the oxygen (O) to form carbon dioxide (CO_2); and the hydrogen (H) unites with oxygen (O) to produce water (H_2O). These two waste products are easily thrown off by the lungs and the kidneys. Carbohydrates are, therefore, ideal energy foods for the ordinary man.

Fats are also composed wholly of carbon, hydrogen, and oxygen, but they are more highly concentrated foods. People who live in cold regions or who engage daily in very heavy work need more of this concentrated food to produce energy. "Fats are fuels for fighters" was a slogan of literal truth which the United States Food Commission used on its posters during the World War. Sugar is also a highly concentrated carbohydrate which the body readily converts into energy.

Proteins contain not only carbon, hydrogen, and oxygen, but nitrogen as well. Nitrogen, as we have seen (page 336), is an essential element of protoplasm. Growth and repair of cells are absolutely dependent upon a supply of protein food.

Until recently it was thought that a great deal of meat was necessary to furnish the energy required for hard muscular work. But investigation has shown that this energy can better be supplied by carbohydrates and fats.

But when for lack of carbohydrates the body is compelled to oxidize proteins to produce energy, certain nitrogen wastes are produced which the body does not throw off so easily. Continued strain of throwing off these poisonous wastes in large amounts may lead to serious disease. The wide-spread custom in America of eating

meat three times a day is not only expensive but also unhealthful. A small amount of meat once a day is all that even a hard-working man needs.

Relative Amounts of Each Group Needed by the Body.
—Since we all need more food for energy than for growth



SUGAR CANE CUTTING

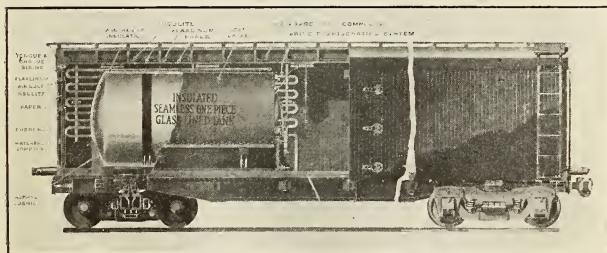
This plant is one of the principal sources of sugar.

and repair, it follows that vegetables and fruit should form the greater part of our food supply. Unless we are given to very vigorous exercise or are subjected to great exposure, we are better off with small amounts of the highly concentrated foods—fats and sugars.

Careful experiment has shown that the average, full-grown American needs each day from two to three ounces of proteins, about four ounces of fats, and a pound of carbohydrates. The weight of food eaten, however, is very much greater than this, as all foods are composed largely

of water, and contain other substances which the body throws off as waste.

Milk.—Milk is one of the most important of the protein foods. The same amount of money will buy more protein in the form of milk than in the form of meat. Besides milk contains other valuable food elements, as we shall see. Pure milk is an essential item of diet for young children; it is altogether the best form of protein for the growing human body; and it might well supplant much of the meat in



Courtesy General American Car Company

2500-GALLON THERMOS BOTTLE

These glass-lined refrigerator tank cars furnish the cleanest, most convenient, and most economical means of transporting milk from the dairies to the city. The transportation of food products has become a highly scientific industry.

the diet of adults. Eggs are also superior to meat as protein food for growing boys and girls.

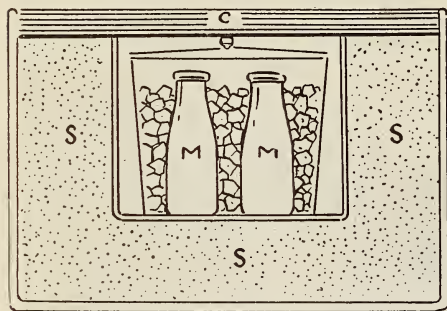
Other Necessary Elements of Food.—Mineral matter such as iron for the red corpuscles, lime for the bones and teeth, and phosphorus for the protoplasm must also be included in our food. Eggs furnish all three of these; milk is rich in lime; but vegetables and the *outer layers of grains* contain the main supplies of these minerals.

It is now known that *iodine* in minute amounts is required by the body. Evidence seems to point to the fact

that goiter, a diseased condition of an important gland in the neck, may result from the lack of iodine.

Iodine is one of the most soluble of all the elements and so the most of it has been washed out of the agricultural soils of the uplands and into the sea. The plants and ani-

mals of the sea all have this element in their make-up. Goiter is a somewhat common affliction in mountainous regions. It is almost unknown to ocean fishing communities where salt water fish forms an im-



HOME-MADE ICE-BOX FOR KEEPING MILK

M, Milk in sealed bottles; packed in ice in covered bucket;
S, sawdust packing around metal nest—a larger pan or bucket serves as a metal nest for the smaller bucket; C, hinged cover with newspaper cleated to it.

portant item of diet. Goiter is rarely found in Japan, where a large proportion of the population use ocean fish or seaweed as articles of diet.

In the mountains of Switzerland, there have been so many cases of goiter that the state is now making a successful effort to combat the disease. Minute amounts of iodine in candy are now fed regularly to school children.

Through the mountain regions and middle section of the United States, departments of health are beginning to recommend iodized table salt for family use, especially urging it for the use of growing boys and girls. Iodized salt can now be bought in cartons at the grocery store.

Other substances called *vitamins* are necessary in minute

amounts for the maintenance of a healthy body. Scientists now distinguish six kinds of vitamins. The discovery of these life principles in various kinds of food has led to a better understanding of what may be regarded as a well-balanced diet.

Pasteurized milk, for example, is now supplemented with orange juice or tomato juice in order to provide all the needed vitamins for infants. The absence of one of the vitamins was found to be the cause of rickets in very young children. Beri-beri was a very common and much dreaded nerve disease in the Japanese army up until about ten years ago. The main diet of the soldiers was polished, or hulled, rice, which was found to be lacking in one of the important vitamins. This vitamin is found in the hulls of rice. The whole grain of the rice instead of the polished grain is now fed to the soldiers, and beri-beri has practically disappeared from the army.

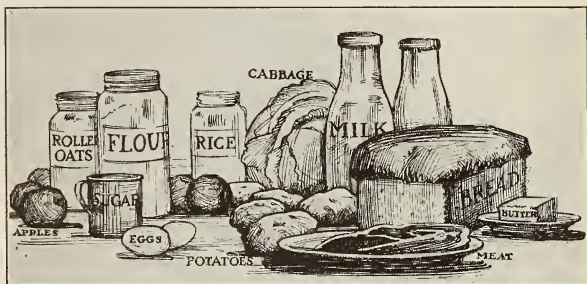
Milk, butter, cheese, eggs, and meat need to be supplemented with vegetables, with whole-grained cereals, and whenever possible with fresh fruits and raw vegetables. A lettuce and tomato salad contains all the necessary vitamins.

The body's need of mineral elements and vitamins further emphasizes the truth that vegetables, fruits, and



MILK DELIVERY IN BELGIUM

whole-grain cereals should form a much larger proportion of the American diet than they now do. Men who live almost exclusively on white bread and meat are starving their bodies for certain very necessary substances, and are overworking their systems to throw off poisonous wastes. When the Food Commission asked during the World War that we eat less meat and more of the dark



ONE DAY'S BALANCED RATION FOR FIVE PERSONS

breads containing the outer layers, or brans, of the cereals they were asking us to do *ourselves* as well as our soldiers and the Allied peoples a favor.

Besides the necessary foods, most individuals desire especial additions of relishes and beverages. These commonly consist of spices, tea and coffee, and other like materials. When used in moderation, they are usually harmless. But they should be avoided by children and not used to excess by adults.

Reference—"How to Select Foods: What the Body Needs," Farmers' Bulletin 808.

Narcotics.—Alcohol, except possibly in exceedingly small quantities, cannot be considered a food, and as a stimulator for the appetite it should not be used. Many careful experiments have shown that while it may stimu-

late the body temporarily, it does not enable it to do more work. Instead, those using it can not do as much work, or withstand as great physical or mental strain, as those not using it.

Even if it were not for the ungovernable appetite which its use almost invariably engenders, and for the degrading influences with which its use is usually surrounded, its physiological action is such as to lessen the body's vitality, decrease its resistance to disease, and dull its nervous and mental efficiency. So surely do deteriorating results follow its steady use that insurance companies regard men who use alcohol as bad risks. Railroads and many great industries refuse to employ users of alcohol.

Whatever scientists may conclude as to the food value of minute quantities of alcohol, they agree that as a steady "stimulating" beverage, it must be classed as a poison.

Careful scientific experiments have also been made upon the effect of tobacco. Although there are differences of opinion about its effect upon fully matured adults, there is no such difference of opinion in regard to its effect upon those who have not stopped growing and are not yet fully matured.

Measurements and comparisons made in regard to the physical development, endurance, and mental ability of a large number of college men have shown conclusively that those who have not used tobacco, as a rule, have better physiques, are better students, and can stand more physical exercise than those who have used it. In the competition for athletic teams it is found that only about half as many of those who have used tobacco make good, as of those who have not used it.

Preparation of Foods.—When foods are appetizing, look good, smell good, and taste good, both the saliva and the gastric juice are secreted in larger quantities, so that

this sort of food, when taken into the system, is more readily digested than food which is not attractive. One of the reasons for cooking food is to render it appetizing, and this should never be lost sight of by the cook. Cooking also softens and loosens the fibers of meats and causes the cell walls of the starch granules to burst, thus rendering it possible for the digestive juices to attack the food more readily. In addition, cooking kills the germs and other parasites that are sometimes found in foods.

To cook food properly is a fine art and requires most careful study and great skill. The science of providing economically the kinds of food necessary and of cooking these properly so that they will be attractive, easily digested and will lose none of their nutritive value, is one that is at present in its infancy. Human beings, like other animals, must have a balanced ration or diet if they are to be most productive economically. They differ from other animals in having a much greater range of food possibilities and in being much more sensitive as to the appearance and taste of food.

Digestion.—Experiment 150.—(Teacher's Demonstration.)—Chop a piece of the white of a hard-boiled egg into pieces about as large as the head of a pin and place in a test tube. Chop up another piece much finer than this and place it in a second test tube. Make a mixture of 100 cc. of water, 5 cc. of essence of pepsin, and 2 cc. of hydrochloric acid. Pour into each test tube enough of this mixture to cover the white of egg to a considerable depth. Shake thoroughly and put in a place where the temperature can be maintained at 37° C. or 98° F. A fireless cooker or a bucket of warm water is good for this. Allow to stand for several hours, keeping the temperature constant. The white of egg is dissolved, the action being more rapid in the second tube. Try the same experiment using water; using dilute hydrochloric acid. Do these have the same effect as when used with the pepsin? The pepsin solution is an artificial gastric juice.

To furnish bodily energy, the cells must be able to combine food with oxygen. To do this the food must be di-

gested or prepared so that it can pass through animal tissue. In the higher animals, a complicated apparatus is provided to accomplish this. In man it is briefly as follows: a long, continuous tube, the food-tract or the *alimentary canal* (Figure 140) extends through the body. Different portions of this tube are adapted to different processes. In the mouth, the teeth grind the food into small bits and mix it with the *saliva*. This is an exceedingly important part of the process, because if the food is not ground fine, the digestive juices can not readily get at it, and the whole process of digestion is greatly retarded. Thus much more energy is expended than otherwise would be. The saliva is necessary to digest some of the starch and to aid in the further digestion.

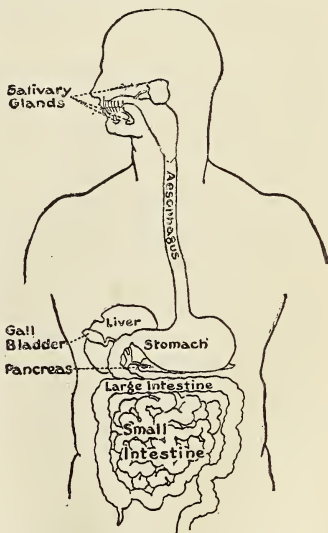


FIGURE 140.—DIAGRAM OF DIGESTIVE TRACT

The food passes from the mouth down the throat and through an orifice to the *stomach*. This is a large pouch which will hold usually from three to four pints. It has muscular walls which enable it to contract and expand, thus keeping the food moving about so that it is thoroughly mixed with the *gastric juice*. The gastric juice is secreted by little glands thickly embedded in the lining of the stomach. Artificial gastric juice was made in Experiment 150. Some of the

proteins (foods containing nitrogen) are digested in the stomach, although the larger part of digestion takes place in the small intestine.

From the stomach the food passes through a valve into the *small intestine*. This is a complexly coiled tube which fills the larger part of the abdomen. The inner wall of the tube is lined with glands which secrete digestive juices, and into the intestine are poured the secretions from two large glands, the *pancreas* and the *liver*. The small intestine is the great digestive organ of the body. Here the fats and oils are digested, and the digestion of the starches and proteins is completed. The small intestine opens through a valve into the *large intestine*, a tube five or six feet long decreasing in size toward the exit from the body. There is no digestive change in the large intestine.

The changes that take place in the food as it passes through the alimentary canal are very complex, but during its progress the valuable part of the food is so changed and prepared that it can be absorbed by the blood and transported by it to the different parts of the body where its energy is needed. Absorption takes place all along the alimentary canal wherever the food has been sufficiently prepared.

In the entire process of digestion of food the only part that can be controlled by the individual is the chewing of the food. It is necessary that the food be ground fine in order that the digestive juices may readily act upon it. This is even more necessary for vegetable foods than for meat. The digestive juices of the stomach and intestine break down the connective fibers of meats and eventually reduce them to a solution. But the woody connective or protective fiber of vegetables does not yield to any digestive juice. Thus if any vegetable foods are bolted without chewing, the digestive juices can reach only the outer surfaces of the unchewed chunks.

Decayed and unbrushed teeth furnish unlimited breeding places for germs. Careful experiments have shown that the health of the body and the mental vigor are greatly increased by properly caring for the teeth. The teeth must be kept clean and all cavities must be properly filled if health is to be maintained.

Keeping the Intestinal Tract Clear.—A certain amount of the food that we eat, such as the woody fibers of vegetables, fruits and cereals, is unusable. These unused parts of food pass on from the small intestine and accumulate in the large intestine. Nothing is more important to health than to keep the large intestine regularly rid of these accumulations. If this is not done, the refuse undergoes bacterial decay and the resulting poisons are absorbed and passed through the body.

It might seem that a diet of concentrated foods, such as fats, cheeses and sweets would be desirable, since most of the material in these foods is used by the body and little is rejected. But there are two objections to an exclusive diet of this sort. In the first place, we are liable to overeat of such foods. In the second place, the muscles of the intestinal tract have sufficient chance for exercise only as they have bulky substances to work upon.

Vegetables and the outer layers of grains provide a large amount of indigestible woody material. The muscles of the intestinal wall are kept strong by the exercise of moving such bulky material along. Daily riddance of intestinal refuse is imperative, in order to avoid headaches, sluggishness, and even more serious troubles. In most cases, the intestinal tract can be kept normally active by exercising care in just a few things: 1. Avoid much concentrated food, such as sugar, fats, and white bread. 2. Eat plenty of bulky foods—whole-wheat bread, whole-grain cereals, vegetables, and fruit. 3. Drink at least

six glasses of water between meals. One should drink during meals also, but not for the purpose of washing down unchewed food. 4. Take regular exercise, especially exercise that involves the muscles of the abdomen.

II. OBTAINING THE OXYGEN SUPPLY

The Process of Breathing.—All animals must have a way to breathe, or energy cannot be supplied to carry on the activities of the body. Different animals breathe in different ways, but the higher vertebrates and man breathe in the same way.

Air enters the body through the nose or mouth, and passes down through the windpipe into the *lungs*. In order to keep out dust and germs, the opening of the nose is supplied with a large number of hairs projecting from the mucous membrane which lines the whole nasal chamber. These hairs and the secretion from the membrane catch and hold most of the harmful particles.

It is most important that air should be breathed through the nose and not through the mouth. Air which enters the lungs through the mouth is not sifted as it is when it passes through the nose; moreover, it is not sufficiently warmed because the mouth passage is much shorter than are the nasal passages. Thus the throat and lungs are irritated by mouth-breathing and are more liable to disease.

Sometimes abnormal spongy growths called *adenoids* partly fill the upper part of the throat. They not only obstruct nose breathing but also furnish a breeding place for disease germs. It is a simple matter for a surgeon to remove them; and unless they are removed, they may result in disordered stomach, quarrelsome disposition, stunted growth, and even stupidity. Most of the cases of adenoids are found in children. Children may or may not outgrow adenoids, but some or all of the evil effects

remain if the trouble is long neglected. In the interest of mental and physical vigor as well as of attractiveness of countenance, the removal of adenoids ought never to be unduly postponed.

At the back of the mouth the windpipe and the throat come together.

When food is being swallowed, the passage into the windpipe must be closed, and this is done by the little valvelike *epiglottis*. If, in swallowing, the epiglottis is not able to close quickly enough, something may pass into the windpipe and cause choking. The windpipe, at the upper part of the chest, branches into two parts, one branch going to each of the lungs.

Action of the Lungs.—The lungs fill the upper part of the chest and infold the heart. In them the air tubes divide again and again, forming a vast network of tubes which grow smaller and smaller until they end in little air sacs. Interlacing with these air tubes are veins and arteries which carry the blood. The tiniest parts into which the blood vessels are divided, the *capillaries*, form close networks within the linings of the air sacs. The air and blood are thus separated by an ex-

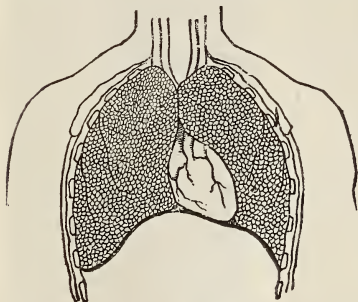


A HUMAN SKELETON

Notice how the bones are arranged to protect the delicate organs.

ceedingly thin animal tissue, which allows an exchange of soluble materials. Thus the blood is able to take up the oxygen needed and to rid itself of the carbon dioxide and other waste products which it has accumulated.

Air is made to enter the lungs in much the same way that it enters a hollow rubber ball that has been compressed and then set free. The air-tight thoracic cavity in which the heart and lungs are situated is inclosed and protected by the ribs, and at the lower part by a dome-



THE LUNGS

They are here pulled aside to show the heart.

shaped muscle called the *diaphragm*. In the normal process of breathing, the muscles of the chest and of the diaphragm act in harmony. When the muscles of the chest pull the ribs so that they move upward and outward, the muscles of the dome-shaped diaphragm cause it to move downward.

These two actions enlarge the thoracic cavity, and air rushes in to fill the open spaces. When the ribs move downward and the diaphragm upward, the air is expelled as in the rubber ball when compressed.

There are then two ways in which air can be made to enter the lungs, the "raising of the chest" and the movement of the diaphragm. In the proper kind of breathing these two movements go on together. The lungs are filled throughout and not simply at either the top or bottom,

Breathing and Health.—Since oxidation in the cells is the source of all bodily energy, the amount of oxygen needed by the body varies according to our occupations. When we are sitting quietly at our desks, we breathe slowly and not very deeply. When we exercise vigorously, we breathe rapidly and deeply to supply the demand of the cells for oxygen.

Shallow breathing renews the air in only a very small proportion of the air sacs of the lungs. Occasional deep breathing is needed to bring fresh air to every air sac in the lungs. Here is another reason for exercise. Those who work indoors are especially in need of daily outdoor exercise.

Correct breathing demands that the body be free and not restricted by tight clothing about the chest or the lower part of the trunk of the body, the *abdomen*. Not only is the right kind of breathing necessary for properly supplying the blood with oxygen, but also that the lung tissues themselves may be properly nourished and cared for. We should be particularly careful about this now that infectious diseases of the lungs are so prevalent.

III. THE BODY'S TRANSPORTATION SYSTEM

Circulation.—**Experiment 151.**—If a compound microscope can be procured, tie a string tightly around the end of a clean finger, and when it has become full of blood, prick it quickly with a sterilized needle. Rub the drop of blood that comes out on a glass slide and quickly examine under the microscope. Notice the great number of round, disklike bodies—red corpuscles. Try to find an irregular-shaped body which, while the blood remains fresh, slowly changes its shape—a white corpuscle. These are rather difficult to find, but can be seen if the drop of blood is thoroughly examined quickly enough.

In order that all parts of the body may be provided with the materials used in building their cells and in doing the work necessary for continued existence there must be

a distributory system. This is necessary wherever diversified work is to be carried on. This necessity has brought into effect the railway and canal systems of the world.



THE CIRCULATORY SYSTEM

Notice the veins (white) are nearer the surface than the arteries (black).

The body is a little world by itself, and it has a most complete and wonderfully adapted system for supplying the material needed and for removing the waste. The center and motive power of this system is the *heart*. The medium of circulation is the *blood*.

The blood passes through different kinds of vessels. Those leading from the heart are called *arteries*, and those returning to the heart are called *veins*.

As a rule the arteries are below the surface of the body where they are protected, but if the finger is placed on the wrist or the side of the face near the ear, an artery can be felt through which the blood is pul-

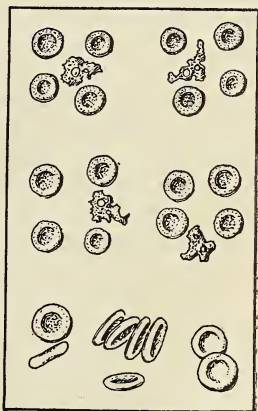
sing. The veins can be seen in the back of the hand and a pin piercing the body anywhere will break open some of the capillaries and cause blood to ooze out. As the arteries proceed from the heart they divide continually, be-

coming smaller and smaller until they terminate in very small, thin-walled vessels called *capillaries*.

The arteries in health are slightly elastic. When a pulsation of the heart forces blood into the arteries, it causes the walls of these tubes to expand. Before the next pulsation, the steady pressure of the elastic artery-walls forces blood into the capillaries and makes way for the next supply pumped from the heart.

The small, thin-walled capillaries into which the arteries subdivide unite again to form veins, through which the blood returns to the heart. Thus the blood is continually flowing from the heart through the arteries and capillaries into the veins and back to the heart.

Composition of the Blood.—When the blood is examined it is found to consist of a watery liquid, called the *plasm*, a great number of little disk-shaped bodies, the *red corpuscles*, and some irregular whitish bodies, the *white corpuscles*.



RED AND WHITE CORPUSCLES

(Greatly Magnified)

The disk-like bodies are red corpuscles.

The *plasm*, an exceedingly complex fluid, is composed largely of water, but carries the nutrient and waste materials supplied by the different organs of the body.

The red corpuscles exist by the millions in every drop of blood, and give the blood its color. They contain in their make-up a substance called *haemoglobin*. This substance unites readily with oxygen in the lungs and readily releases it to the cells. The red corpuscle is especially

adapted to the one work of carrying oxygen. When the haemoglobin of the red corpuscles is carrying a load of oxygen through the arteries, it is of a bright red color. But when it returns through the veins after having parted with its load of oxygen, it is of a darker shade of red.

The white corpuscles are protoplasmic cells possessing the power of movement and even of working their way out of the blood vessels. They are the soldiers of defense of the human body. We shall discuss them more fully later.

Deliveries to the Cells.—The main lines of transportation, the arteries and veins, do not make *direct* deliveries of food or oxygen to the cells nor receive wastes directly from them. It is only in the tiny, thin-walled capillaries that this exchange goes on.

As the blood slows up in the capillaries, some of the plasm is forced, by the pressure of the arteries, through the thin, capillary walls. This colorless liquid, as soon as it leaves the capillaries to occupy the spaces between the cells, is called *lymph*. The red corpuscles continue along the blood stream without ever leaving the capillaries.

The lymph delivers its load of food and oxygen to the cells, and receives carbon dioxide, water, and nitrogenous wastes in return. Some of the lymph returns through the capillary walls and is carried by the veins back to the heart. The rest of the lymph is gathered up by a separate system of transportation tubes, called the lymphatics. These carry the lymph to the left side of the neck and empty it into a large vein there.

Keeping the Stream of Transportation Pure.—The blood must be kept steadily clear of cell wastes in order to prevent the cells from being poisoned by their own waste matter. The lungs, the kidneys, the liver, and to some

extent the sweat glands of the skin do the great work of purification. Through the lungs, carbon dioxide and water vapor escape. The kidneys in health are wonderfully constructed filters. The blood passes through these filters without any loss of food substances. But certain wastes in solution are filtered out. Chief among these are the poisonous nitrogenous wastes. It can be seen, in the light of this fact, why too heavy a diet of proteins puts a great strain on the kidneys.

All the blood in the body passes through the liver once every three or four minutes. Here certain wastes are broken down or poisons in the food destroyed. It is the liver that destroys nicotine or oxidizes alcohol to prevent them from doing injury to the system. But if these poisons come steadily or in too great abundance, the liver is often crippled or destroyed by its prolonged fight. The wastes from the liver are sent out of the body directly by way of the alimentary canal or by way of the blood and through the kidneys.

The liver is a very important, patient, hard-working organ. When we accuse it of not working, we really should say that it is over-working; it is doing its best to atone for our over-eating and lack of exercise. We do not need blood tonics to keep our blood pure. We need simple food and exercise suited to our individual demands. If we allow gluttony and laziness to cripple our liver and kidneys as we grow older, oceans of blood tonic will never do their work for them.

•

The Heart, a Muscular Pump.—The heart is a muscular force pump composed of four chambers, two *auricles* and two *ventricles*. It is shaped somewhat like a pear and is situated almost directly behind the breastbone. The blood coming back from the veins flows into the right auricle, a chamber with rather flabby walls. From here,

it passes through a valve into the right ventricle, which is a chamber with very thick muscular walls. From the right ventricle, the blood is driven out through the arteries, capillaries, and veins of the lungs, where carbon dioxide is given off and oxygen absorbed by the red corpuscles.

Returning from the lungs, the blood enters the left auricle and when this becomes full, passes through a valve into the left ventricle. This has such powerfully muscular walls that it is able to force the blood throughout the body and back again to the right auricle. As the blood leaves either ventricle, there are valves that close and prevent its return. If the hand is placed a little to the left of the breastbone, the strong contraction of the ventricle can be felt.



CROSS SECTION OF THE
HUMAN HEART

Showing auricle, ventricle, and ventricle valve.

Care of the Heart.—The heart is a wonderful organ. It works all the time for all parts of the body. If there is food to be digested, the heart pumps more blood to the stomach. If lessons are to be studied, the heart pumps more blood to the brain. If there is muscular work to be done, the heart pumps more blood to the muscles. Surprise, fear, anger, and other emotions set the heart to beating faster. It is amazing that any muscular tissue can endure the steady drag of uninterrupted work with frequent strains, and yet remain strong and healthy.

But the heart thrives on exercise. Without exercise it tends to grow flabby like any other muscle, and is less able to endure sudden strain. But exercise must be suited to the individual. Whoever is unaccustomed to exercise must begin it slowly and increase it gradually as the heart grows stronger. This is the secret of successful athletic training. One should stop work or play when one begins

to feel tired or when the heart begins to beat violently. Games or work in which a person is compelled to drive himself to effort in spite of dragging fatigue should be avoided. This advice applies most emphatically to those who are under eighteen, or over forty-five years of age.

All athletic trainers know that plenty of sleep, plenty of wholesome food, and complete abstinence from the use of alcohol and tobacco are necessary to the building of a strong heart. Alcohol is a positive poison to the cells of the heart. Its long-continued use results in the substitution of fatty cells for the muscle cells of the heart. The use of tobacco also handicaps the heart, but it is particularly harmful to the heart of a growing youth. A report of a United States surgeon-general shows that of the candidates who fail to qualify for West Point each year on account of heart weaknesses, practically all are users of tobacco.

IV. THE BODY'S DEFENSES AGAINST BACTERIAL DISEASE

The Wall against the Enemy.—The body has a remarkable system of defenses against bacterial disease. As we have said (page 397), the skin itself serves as a wall of protection. Germs entering the nose meet various kinds of entanglements which prevent most of them from going farther (page 498).

The skin performs another vital service. By means of the sweat glands, it maintains the heat of the body at an almost uniform temperature. This is absolutely necessary if the body is to continue in health. In fever the sweat glands cease to operate, and the temperature of the body increases.

The skin performs its duties well only as the capillaries of the skin are capable of receiving or excluding a blood supply quickly. In a skin smothered in unnecessarily heavy clothing, the capillaries lose their power to react

quickly. Often the result is that blood which should be warming the skin is congested in the mucous membrane of the nose, throat, or lungs, making conditions favorable for "catching cold." The thing of chief importance is to dress warmly in winter but not so warmly that the skin becomes soft and tender (page 132). The skin needs to be kept ventilated as well as clean.

The First Line of Defense.—If the outer wall of skin is broken or germs enter the body by way of the nose or the mouth, the first line of defense consists of the white corpuscles. These gather at the point of attack and make their way through the walls of the capillaries to fight the invading germs.



A WHITE
CORPUSCLE
DIGESTING A
GERM
(Greatly
Magnified.)

When a white corpuscle comes in contact with a disease germ, the body of the corpuscle takes the germ into it and tries to digest it. The germ in turn tries to multiply inside the corpuscle and to feed on it. Unless the germs increase in number too rapidly, the white corpuscles come off victorious.

The Main Lines of Defense.—The blood also provides other "anti-substances" that are probably even more important than white corpuscles in fighting disease. Some of these lend vigor to the white corpuscles, others kill disease germs and still others counteract germ poisons.

The reason why one who is vaccinated is immune from smallpox is that the vaccine causes the body to produce anti-substances in great abundance which prevent the smallpox germ from living and multiplying in the body. These anti-substances remain in the body for a number of years, and keep the body protected. Vaccination, and vaccination alone, is responsible for the conquest of this

plague which in the 18th century killed sixty million people in Europe.

When disease bacteria get established in the system, they secrete a poison called *toxin*, which is absorbed by the blood and carried throughout the body, thus poisoning many other parts besides those immediately attacked by the bacteria. The cells of the body at once begin to secrete a substance to counteract this poison, an *antitoxin*. If the vitality of the patient is great enough, sufficient antitoxin will be secreted to neutralize the effect of the toxin and the disease will be overcome.

Of late years it has been found that these antitoxins can be artificially supplied or caused to develop. Thus the system may be aided in neutralizing the effect of the toxin. The purpose of administering antitoxin, as in diphtheria, is to provide anti-substances more quickly than the body produces them. Thus the terrible toxins are counteracted immediately and prevented from poisoning the cells of the body. With no toxins to weaken them, the white corpuscles are able to overcome the germs of the disease quickly.

A generation ago, diphtheria took the lives of thousands of children every year. To-day diphtheria antitoxin has removed most of the dread of this disease. Prompt treatment is the one essential.

In vaccinating against typhoid, millions of dead typhoid germs are injected into the blood. It has been proved that these dead germs so stimulate the body to produce anti-substances that the individual is protected for months against the disease. In our war with Spain typhoid killed more soldiers than did the Spanish guns. Inoculation for typhoid had not been developed at that time. In the recent Great War, the soldiers of the American armies were compelled to undergo inoculation. So effective is this inoculation as a preventive against the disease that

out of the millions of soldiers in the field, fewer than 250 died of typhoid fever. So carefully are the vaccines and antitoxins made at present that if proper care is taken in their injection, there is almost never any ill effect from their use.

Scientific Control of Dread Diseases.—Every year we are learning more and more about the prevention and cure of disease. The discovery of the nature of yellow fever and the manner of its being conveyed has resulted in stamping out the epidemics that used to afflict the South. The Americans were able to build the Panama Canal because they were able to protect the workmen from yellow fever and malaria. The death rate from tuberculosis is decreasing every year, because more and more people are learning that it is a curable disease if taken in time. Promptness of treatment, rest, and proper food are restoring thousands of tuberculosis victims to health annually.

Diseases like smallpox, bubonic plague, typhoid fever, and diphtheria, which formerly swept over cities and even over continents like destroying angels, are now well under control. Another wonderful achievement in the field of medicine is the recent invention of a cure for the terrible "sleeping sickness", a disease which makes half the continent of Africa uninhabitable. This one drug promises, therefore, to restore half a continent to the use of man.

Prominent, however, above everything else stands out the fact that cleanliness is the great protector of health. Those communities that have well-built sewers, clean streets, clean milk, and clean water are healthy. The community through its boards of health must protect the individual from the germs of contagious and infectious diseases, for he can not do this by himself. Persons that eat pure food, drink pure water, breathe pure air, and keep their bodies pure are usually healthy.

Guide Posts to Health.—Good health is man's greatest asset. If he is to attain his highest power he must maintain his health. His muscles must be exercised so as to stimulate the cells to grow and to throw off their waste products. The skin must be frequently bathed so as to remove the dirt and waste materials that clog the pores. The body must have sufficient rest and sleep so that the cells will not be worn out faster than they can be reproduced.

One must have plenty of food but not too much, or the stomach and other organs will suffer from overwork. The use of stimulants, such as tobacco, alcohol, and all other harmful drugs must be avoided since all of these interfere with the proper growth, development, and work of the various cells of the body. The cure-all patent medicines, which do not cure at all but which simply dope the sensibilities of the individual, should be shunned as poison. Fresh air and sunshine are the best and surest preventives of disease; and when these are combined with proper rest, food, clothing, exercise, and bodily cleanliness, there is little danger of sickness except from highly contagious diseases.

Every day each person probably receives into his system thousands of disease germs. Usually it is only when the vitality of the body is low that these germs are able to establish themselves. Right living is the great disease preventer.

Oral Reports.—1. Report to class on a method of disinfecting and caring for a shallow cut, scratch, or puncture. What are safe and efficient disinfectants for various kinds of home use. 2. Demonstrate the use of a tourniquet to stop bleeding from a severed artery in the arm or leg.

V. COMMUNICATION AND CONTROL

Wonderful as are all the workings of the human body that we have studied, the nervous system of man stands

out as the most marvelous thing of all creation. By means of it communication with the outside world is carried on, all bodily activities are regulated, and

man's supremacy over the rest of creation is established. The brain is the commander-in-chief of the entire cell-community that makes up the body of man. The spinal cord and certain nerve centers distributed through the body have certain duties delegated to them, but they are all under the sway of the brain.



THE NERVOUS SYSTEM OF MAN

Notice how the nerves are distributed to all parts of the body.

The Senses.—In order that the brain may communicate with the outside world and so be able to protect the animal from destruction and to provide for its well-being, animals are provided with a number of *sense organs* which communicate with the brain by nerves.

These nerves are of two distinct kinds, different not only in the work they do, but also in the shape and make-up of the nerve cells themselves. One set of nerves carries impulses to the brain. These impulses

mean nothing to us until the brain translates them into sensations. That is, the eye does not see, the ear does not hear, the tongue does not taste, and the finger does not feel. But impulses are carried over nerves from these parts of the body to the brain, and the brain translates these impulses into seeing, hearing, tasting, and feeling. In answer to impulses received, the brain sends out to various cells of the body commands to act. These out-going nerves are altogether different and altogether separate from the incoming nerves.

The most conspicuous senses of the human body are those of sight, hearing, taste, smell, touch, warmth, and cold. The sense of sight we have discussed in connection with the subject of light.

On the *tongue* and in the *nose* are cells which transmit to the brain the impressions produced upon them by different qualities, the one of solutions and the other of gases. The sensations thus produced are called *taste* and *smell*.

The sensation of *touch* originates in the skin and is much more acute in some portions than in others. The tips of the fingers in the blind are often trained to such delicate perception that they, in a great degree, take the place of the lacking sense organ. These sensations, like all others, are carried to the brain by the nerves and there interpreted into the sensation of touch.

It is only in recent years that cold and warmth have been recognized as sensations separate from that of touch. But it is now known that the skin is equipped with three entirely different kinds of nerves corresponding to the three senses of touch, cold, and warmth.

Sound and Hearing.—Experiment 152.—Arrange a large, wide-mouthed bottle with a small bell suspended in it from the stopper and a delivery tube extending through the stopper. (Figure 141.) Attach the delivery tube by a thick-walled rubber tube to an air pump and exhaust the air from the bottle. Shake the bottle so that

the bell can be seen to ring but does not strike the sides of the bottle. Can the sound be heard distinctly?

Experiment 153.—Suspend a pith ball by a light thread so that it may swing freely. Strike a tuning fork and quickly place it in very light contact with the pith ball. The ball will be set in motion by the vibrations of the tuning fork.



FIGURE 141

In Experiment 152 it was found that if the air was exhausted and the bell did not touch the sides of the bottle, almost no sound was heard when the clapper of the bell showed that the bell was ringing. This shows that the sounds we usually hear are transmitted in some way by the aid of the air. In Experiment 153 the sounding body was seen to be vibrating. Since these vibrations set the pith ball moving, we may understand that the air surrounding the tuning fork must also have been set in motion.

Sound has been found to be a wave motion in a material medium. If a scratch is made on the end of a long log, it can be heard if the ear is placed at the other end of the log, when it can not be heard if the ear is away from the log. In this case the medium is the wood.

If a stone is dropped into a quiet pond, the rippling waves developed will extend often to the farthest shore of the pond, but a chip floating near where the stone fell will not be moved from its position except up and down. Thus the waves traveled outward from the point of origin, but there was no outward movement of the water. If a long rope, attached at one end and held in a horizontal position, is suddenly struck with a stick, a wave motion will travel along the rope from end to end, but the particles of the rope will simply move up and down. It is in a similar way to this that the sound waves travel, but the particles which transmit the sound only move back and forth through small distances. (Figure 142.) An echo

is simply a reflection of sound waves from some obstruction they meet.

The *ear*, which is the sound transmitter of the body, consists of the outer ear, which is so arranged as to catch the sound waves and converge them upon the ear drum. The *ear drum* is a thin membrane stretched tightly across a bony opening and vibrates when the air waves strike it, as a drum does when struck by the drumstick. On its inner side the drum is attached to the inner ear by a chain of three bones. The sensitive cells of the inner ear transmit the impressions made by the sound vibrations through the *auditory nerve* to the brain, where they are interpreted into the sensation of *sound*.

The drum head of the ear is easily broken, and therefore no hard instrument should ever be thrust into the ear. There is an old saying that one should never pick his ear with any kind of hard instrument having a smaller point than one's elbow. Immediate and skillful attention should be given to any inflammation of the ear. If neglected it may lead to deafness or even to an exceedingly dangerous abscess in the bone back of the ear.

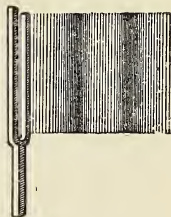
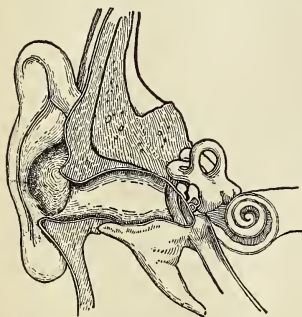


FIGURE 142



CROSS SECTION OF THE HUMAN EAR

The Work of the Nervous System.—Probably the most wonderful thing about

the nervous system is its ability to coördinate the activities of the body; that is, to make all cells work in

harmony toward the doing of a particular thing. For example, a mother offers her young son a piece of cake. The child's brain receives the pleasant impression of the cake through the nerves of the eyes and the nose. In response to these impressions, a message is sent to the salivary glands, and the boy's mouth begins to "water." The boy receives the cake, puts it to his mouth, bites off a piece, chews it, and swallows it. The muscles of the stomach begin their churning movement, and the glands of the stomach produce gastric juice.

Every one of these activities is carried on in response to a message from the nervous system. Receiving, biting, chewing, and swallowing the cake are *voluntary* activities, but the activities of the salivary glands, the gastric glands, and the muscles of the stomach are *involuntary*. These glands and muscles are commanded by the governing nervous system to do the right things without any conscious effort on the part of the child. It is fortunate for us that these vital activities and others that are necessary to the continuance of life are not dependent on our voluntary efforts.

The brain and spinal column, with the aid of the maze of nerves and branches connecting them with all parts of the body, have direct charge of all voluntary actions. Certain actions that are voluntary may at times be performed involuntarily. For instance, the hand recoils from a hot stove and the eye blinks at the sudden appearance of an object before it. These are called *reflex actions*, because the touch or sight impulse goes only as far as the spinal cord, and from there a message for action is returned directly. Reflex actions generally serve to protect some part of the body, and the nervous system provides for carrying out the protective act with the least possible delay.

Involuntary activities are under the control of small

autonomic, or "self-governing," nerve centers scattered through the body. But these so-called "self-governing" centers are all connected with the spinal cord and brain, and are compelled to act in harmony with each other.

Habits.—We have seen that every activity is the result of a message that is sent out from the nerve centers. The first time a message for voluntary action is sent out, it passes over the nerve circuit with difficulty, and the resulting action is awkward. But repeated sending of the message and repeated practice of the action finally produce habit or skill. All of our much-repeated activities grow into habits. It is well for us that this is so, and that the doing of an habitual thing requires so little mental effort. If it were not so, we should be worn out each day with the doing of simple things such as dressing ourselves, eating, walking, etc.

But we are also constantly forming habits that are of moral, social, and commercial importance. Since most of the habits we cultivate stay with us for a lifetime, it is impossible to overestimate the importance of cultivating the right sort of habits in youth.

Care of the Nervous System.—General health of the body and efficiency of the nervous system ordinarily go hand in hand. Plenty of sleep is necessary to keep the nervous system working at its best. The required period of sleep varies from about seven or eight hours for adults to twelve or thirteen hours for children of from five to seven years of age. Exercise and wholesome food are as necessary to the nervous system as to the rest of the body.

Nagging worry is one of the worst enemies of the nervous system. Most worry is unnecessary. It is simply a vicious habit that can be overcome. Constant use of alcohol tends to deform or destroy nerve tissue. Skill and

precision of author, artist, musician, or mechanic is the result of long training of the nervous system. These qualities are invariably impaired and eventually destroyed by the steady use of much alcohol.

SUMMARY

Man is the highest form of animal creation. The practical purpose of the study of all science is to provide the most favorable condition for human life. In both plant and animal life, the cell is the unit of life processes. Single-celled plants and animals carry on all the activities necessary for their own existence. But man and all the higher forms of life are made up of many cells. Each kind of cell has its own duty to perform in the cell community. Cells of a kind are grouped together into tissues in order to accomplish the work of the cell on a large scale. If the cells of any tissue fail to work properly, the welfare of the entire cell community is affected.

Among the most important kinds of work carried on by various tissues of the cell community are: 1. the digestion of food; 2. the obtaining of the oxygen supply; 3. transportation of necessities to all parts of the body; 4. the defending of the body against bacterial disease; and 5. the control of all the workings of the tissues.

The elements which enter into the structure of the human body are comparatively few and are abundant in the world about us either separately or in compounds. The three great groups of foods are known as carbohydrates, fats, and proteins. All foods provide energy to carry on the activities of the body and to maintain its heat; but the best energy foods are the carbohydrates and the fats. The proteins, which contain the element nitrogen, are essential to growth and repair of body cells. The body also requires water and salt, iron for the red corpuscles,

lime for the bones and teeth, and phosphorus for the protoplasm. It is now known that iodine in minute amounts is also required by the body. Other substances called vitamins are necessary in very small amounts for the maintenance of the healthy body. These are found in abundance in vegetables, fruits, and whole-grained cereals.

Alcohol as a beverage must be classed as a poison. There are differences of opinion as to the effect of tobacco upon fully matured adults, but it is agreed by all authorities that tobacco is harmful to individuals who are not yet fully matured.

In order to make food usable for the body, the process of digestion is essential. The principal organs concerned in the process of digestion are the stomach with its gastric juices, the small intestine, the pancreas, and the liver. In the large intestine there is no digestive change.

Nothing is more important to health than to keep the large intestine regularly rid of the accumulations of the unusable portions of food which the digestive system discards.

The body must have a supply of oxygen in order that oxidation may occur in the cells to furnish heat and energy. The lungs are the organs of the body through which oxygen is supplied to the blood and carbon dioxide is delivered to the outer air. It is important for many reasons that we should breathe through our noses. Any defect which prevents this should be remedied. Correct breathing demands that the body be free and not restricted by tight clothing. Occasional deep breathing is needed to bring fresh air to every sac in the lungs.

The body's transportation system is made up of the heart, a muscular pump, arteries which carry the blood from the heart to the tissues, veins into which the blood is gathered to be returned to the heart, and capillaries from

which deliveries of food and oxygen are made to the cells. The blood is composed of a liquid called plasm and innumerable disc-shaped bodies called red corpuscles and some irregular shaped bodies called white corpuscles. The red corpuscles are the oxygen carriers.

The body has remarkable systems of defense against bacterial disease. The skin itself effectively walls out almost all germs. It also performs the vital service of maintaining the heat of the body at an almost uniform temperature. If the outer wall of skin is broken, the white corpuscles rush in great numbers to the break to defend the body against invading germs. The blood also provides other anti-substances for defense. Some of these lend vigor to the white corpuscles, others kill disease germs, and still others counteract germ poisons. It is through knowledge of these anti-substances that scientists have been able to prepare vaccines and antitoxins with which to fight disease.

Wonderful as are all the workings of the human body, the nervous system of man stands out as the most marvelous thing of all creation. By means of it, connection with the outside world is carried on, all bodily activities are regulated, and man's supremacy over the rest of creation is established. The brain and the spinal cord are very important parts of the nervous system.

QUESTIONS

Why may man and other higher forms of plant and animal life be called cell communities?

What are the three groups of food? What is the use of each food group? What are the relative amounts of each group needed by the body? Why is milk so important a food?

Mention some mineral substances needed by the body. Why is iodine essential to the health of the body?

What are the best sources of mineral elements and vitamins needed by the body?

Why should alcohol and tobacco be avoided, especially by those who have not reached their maturity?

What organs are concerned in the process of digestion?

What are some daily rules to be followed in order to keep the intestinal track clear?

Explain the process of breathing. Why is it important that we should breathe through the nose? Why is occasional deep breathing essential to health?

How is the circulation of blood carried on in the body? What is the composition of the blood?

How are deliveries of food and oxygen made to the cells?

What is essential to keeping the blood stream pure?

What care should be given the heart in order to maintain it in a healthy condition?

What two services does the skin render?

What is the work of the white corpuscles?

What use have scientists made of their knowledge of anti-substances in making effective war on disease?

What are the senses?

How is sound conveyed and by what means are we able to hear sound?

What are voluntary activities and involuntary activities?

Why is it important that good habits should be formed early?

What are some rules for us to observe if we are to have healthy nervous systems?

CHAPTER XVIII

MAN'S DEVICES FOR CONTROLLING ENERGY

*There's always work
And tools to work withal, for those who will.*—Lowell.

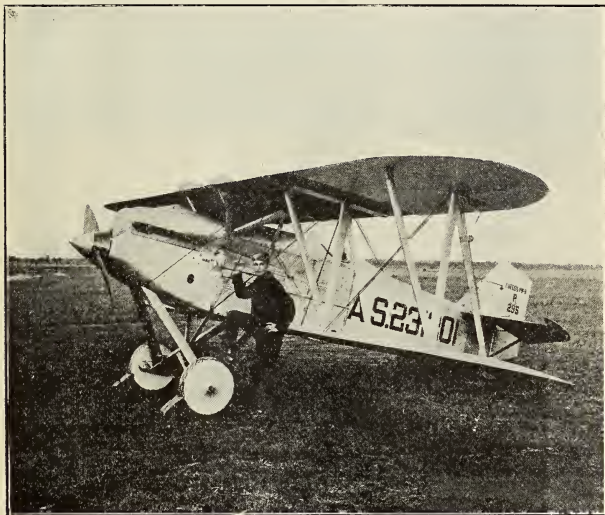
The work of animals, except under man's careful training or control, is confined to the energy that lies in their own muscle cells. Man's intellect has enabled him to use his energy in many intricate ways and to multiply his strength many-fold by the contrivance and use of tools. But he has done more than devise tools to increase his own efficiency; he has invented machines to harness various forms of energy that exist in the world about him.

The old Greek runner who in 490 B. C. carried the appeal for help from Athens to Sparta, 140 miles, in 36 hours, still commands our admiration for his speed and endurance. But to-day, even if there were no electrical communication, a racing airplane might make the trip of the Greek runner in little more than half an hour. The "pony express" that carried Lincoln's inaugural from St. Joseph, Missouri, to Sacramento, California, 1400 miles, in 7 days and 17 hours established a proud record. But in June, 1924, Lieutenant Maughan of the United States Air Service made a flight from New York to San Francisco, 2680 miles, in less than 18½ hours.

The railway has made San Francisco and New York nearer neighbors than were New York, Philadelphia, and Baltimore in colonial times. The steamship has cut

the months of journeying of the sailing ship across the Atlantic to almost a corresponding number of days. And now the airship Los Angeles has made the trans-atlantic trip in half the time of the fastest steamship.

This illustrates what the invention and use of machines in a single field has accomplished. In numberless ways it



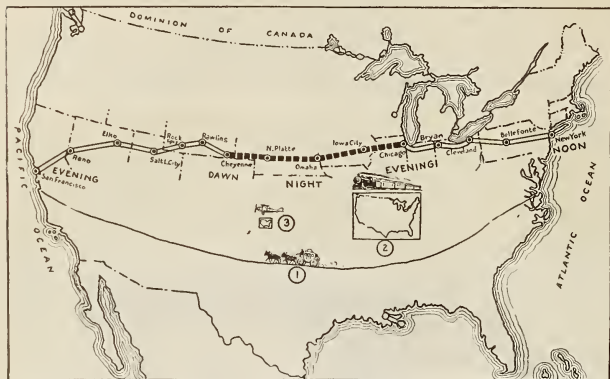
Official U. S. Army Air Service

LIEUT. MAUGHAN WITH HIS CROSS COUNTRY AIRPLANE

can be shown how modern man's ability to utilize so many forms of energy has made his life very different from that of his forefathers. Machinery makes the work of one farmer equivalent to that of thirty in the days of Washington. Without machines there could be no large cities, no manufacturing on a large scale, no rapid transportation, and none of the conveniences that make modern life more

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comfortable for the average man than it was for the prince of a century ago.



Courtesy U. S. Post-Office Department

MAP SHOWING HOW THE LOCOMOTIVE AND AIRPLANE HAVE DWARFED DISTANCES

I. SIMPLE MACHINES

More and more man is relying upon machines driven by nature's energy to do the work he has heretofore done by his own physical exertion. The mowing-machine, the sewing-machine, and the automobile are comparatively recent examples of such inventions. All these intricate devices, however, have a few simple machines as their basis. These basic machines are the lever, the wheel and axle, the pulley, the inclined plane, the wedge, and the screw.

Friction.—If we attempt to slide a box along a level floor, we find that we have to overcome resistance or do work. If we put rollers under the box there is less resistance, but some resistance always develops when two surfaces are moved over each other. This resistance is



Courtesy International Harvester Co.

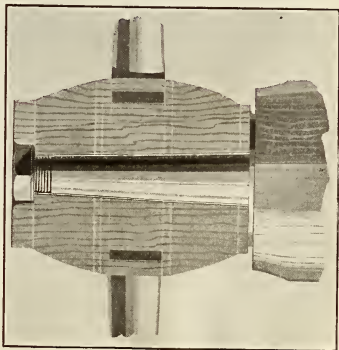
LABOR-SAVING MACHINERY

Two men with a tractor operate two binders and two shockers. The shocker is an invention which receives the bundles of wheat, automatically assembles from 8 to 11 of them into a shock, and deposits the shock right side up. Each shocker saves the labor of at least two men.

called friction. The rougher the two surfaces, the more the friction; and the smoother they are, the less the friction.

To lessen friction we make surfaces that slide over each other very smoothly and oil them.

The fact that a wheel or roller lessens friction is applied in the invention of roller and ball bearings. In old-fashioned buggies and wagons, the hub of the wheel fitted over the axle and turned on it. To-day even toy wagons are equipped with roller or ball bearings.



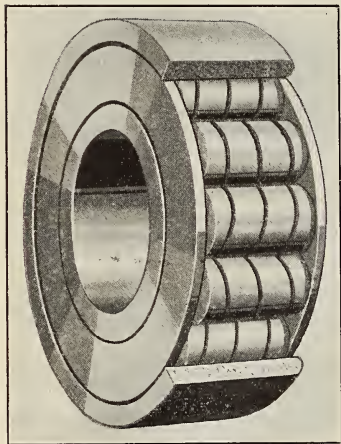
OLD-FASHIONED COMMON BEARING

The wagon hub is here cut away to show the axle in its metal lined bearing.

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Bicycles, automobiles, and all well-constructed machines are equipped with such bearings wherever possible.

In an efficient machine, friction is reduced in every possible way in order to avoid as far as possible "loss of energy." The employment of roller and ball bearings and the generous use of suitable lubricants have done



ROLLER BEARINGS

much to lengthen the life of machinery in use. But no matter what we do, some of the work exerted on a machine is used up in overcoming friction, and eventually friction wears out the machine. In some of the simple machines, especially the wedge and the screw, friction is always so great that the machines are not very efficient.

Why do screws sometimes break off sharply when they are being driven into hard

wood? Why does a good carpenter drill a hole in hard wood before he attempts to drive a screw into it?

The Lever.—Experiment 154.—(A) Bore a small hole through a meter-stick at each of the decimeter divisions. Place on the table a small board so that its edge shall be even with the edge of the table. Weight or clamp the board to the table. Into the edge of the board drive a round-finish, small-headed nail so that it will project horizontally over the edge of the table. Slip the nail through the center hole of the meter-stick. (Figure 143.)

Hang a weight of 400 g. from the first decimeter hole. Find out how much weight will be required at each of several holes on the other side of the nail in order to balance the 400 g. weight. In each case,

multiply the weight on each side of the nail by its distance from the nail and compare the results. Lift one end of the meter-stick 10 cm. above the edge of the table, and note how far each weight moves. Multiply each weight by the distance it moved up or down, and compare the results.

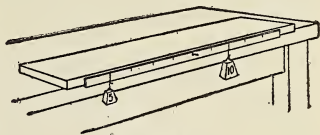
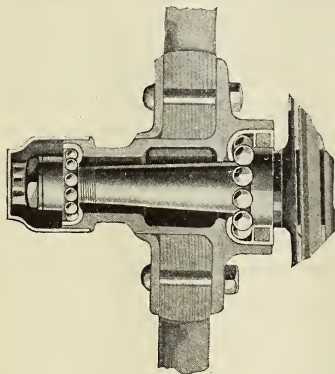


FIGURE 143

(B) Attach a small spring balance by a short string to one of the end holes of the meter-stick.

Slip the nail through the hole next to it. Hang a weight of 400 g. from any one of the other holes. Pull down on the spring balance until the meter-stick is in a horizontal position. Note the pull on the spring balance and make the same computations as in (A). Repeat the experiment and computations by hanging the weight from several different holes.

(Exact accuracy in these experiments would require a consideration of the weight of the meter-stick itself, but for the purposes of this experiment, results will be nearly enough accurate without this.)



BALL BEARINGS

The lever was probably one of the first machines used by primitive man. He pried up rocks and pried open logs to get the roots and small animals he needed. It was to him simply a convenient way of using a stick. But when Archimedes, the greatest

mathematician of ancient times, worked out the principle of this simple machine, he was so much impressed with the mechanical advantage to be derived from its use that he said, "Give me a fulcrum on which to rest and I will move the earth."

He found, as was indicated in Experiment 154, that the longer the power arm is than the weight arm, the greater is the weight a given force can lift, but the smaller the distance it can lift it. If the experi-



FAMILIAR APPLICATIONS OF
THE LEVER

ment could have been accurately conducted, it would also have proved that the power multiplied by the distance the power moves is equal to the weight multiplied by the distance the weight moves.

Careful experiment has shown that this last statement is true for all machines, and so it is sometimes called the law of machines. It can be stated in another way: What is gained in power is lost in speed and what is gained in speed is lost in

power. Notice the machines you are familiar with and observe how this law holds good. All of us are using different kinds of levers every day. Balances, scissors, nut-crackers, wheelbarrows, forceps, and the treadle of a sewing-machine are all examples of levers.

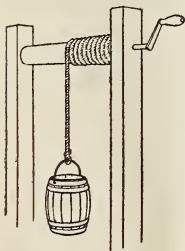


FIGURE 144

Wheel and Axle.—The windlass used to lift water out of a well and the capstan of a boat are the most familiar examples of this form of machine. (Figure 144.) The wheel and axle is simply a modification of the lever. (Figure 145). The power travels through the distance of the circumference of one

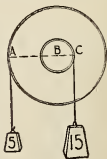


FIGURE 145

wheel (A) while the weight travels through the distance of the circumference of the other wheel, or axle (C). If

the circumference of the power wheel is three times the circumference of the weight wheel, a force of 5 pounds exerted on the power wheel will lift a weight of 15 pounds on the weight wheel.

The Pulley. — Experiment 155. — (A) After well oiling some small pulleys arrange one of them as in Figure 146, having a weight of about 500 g. on one end of the cord and a spring balance on the other. Slowly pull down on the spring balance and note the reading on the scale. Allow the balance to

rise and note the reading. Friction accounts for the difference between the first and the second reading of the scale. Average the two readings and see how nearly the average equals the weight on the other end of the cord. May we say that the force exerted by the hand is

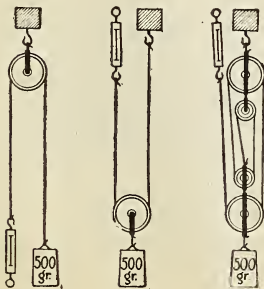
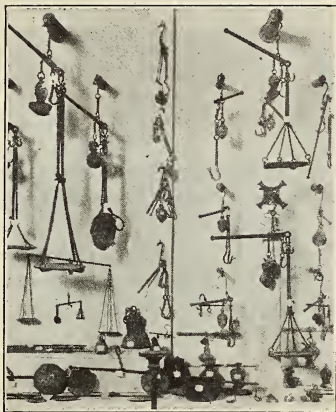


FIGURE 146

FIGURE 147

FIGURE 148



THE LEVER AS USED BY THE ROMANS FOR WEIGHING

These scales were dug up at Pompeii and are about 2000 years old.

equal to the weight? Does the hand move through the same distance as the weight?

(B) Arrange the pulleys as in Figure 147. Allow the balance to descend, noting the force recorded on the scale. Pull up on the balance, noting again the reading on the scale. Find the average between the two forces, which may be called the true force. Is the force now exerted by the hand equal to the weight? If not, what are the relations of these two forces?

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Note the distance moved by the hand and also the distance moved by the weight. How do they compare?

(C) Arrange the pulleys as in Figure 148. Make determinations similar to those in (A) and (B). How does the force exerted by the hand now compare with the weight? How does the distance moved by the hand compare with that moved by the weight?

It is sometimes exceedingly convenient to change the direction of a force even if no other advantage is gained. To do this, a rope may be passed over a wheel, and thus one may by pulling down lift up the weight. Such an arrangement is called a fixed pulley. (Figure 146.) The cord in passing around the wheel simply has its direction changed, but there is no gain for the user of the machine either in power or in distance.

If now the pulley is arranged as in Figure 147, it is no longer a fixed pulley but is movable. It is evident in this case that the weight is supported not by a single cord as in the fixed pulley but by two cords, the part of the cord attached to the beam and the part of the cord held by the hand. The hand will need to move twice as far as the weight is lifted.

A number of pulleys may be arranged as in Figure 148 so that the movable pulley with the weight attached is supported by several cords. In this case each section of the cord supporting the movable pulley sustains its proportion of the weight, and the power is as many times less than the weight as there are cords supporting the movable pulley. But the gain in power means a loss in distance. The power will have to travel as many times farther than the weight as there are cords supporting the movable pulley. An arrangement like this enables a small power slowly to lift a large weight.



A PULLEY

The Inclined Plane.—When the ancient Egyptians built the great pyramids, it was necessary for them to raise huge blocks of stone to great heights. It would have been next to impossible for them to do this simply by using brute force. Some simple machine was necessary. They probably used the same kind of machine that is used to-day in rolling a barrel into a wagon or in grading wagon roads or railroads over mountain passes—an inclined plane. The more gradual the inclination up which the weight travels, the smaller the power required to lift the weight. Again, what is gained in power is sacrificed in distance.

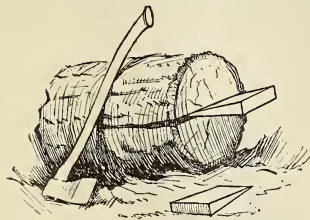


Wide World Photo

AN INCLINED PLANE

This spiral approach leads from the business section of Hastings, Minnesota, to the bridge spanning the Mississippi to the residential section.

The Wedge.—The wedge consists simply of two inclined planes placed back to back. It is principally used in forcing substances apart, as when wedges are used to split wood and stones, or as needles and pins are used in pushing apart the fibers of cloth. Axes and chisels and most cutting tools except saws act on the principle of the wedge.



USE OF THE WEDGE

The Screw.—The screw is simply an inclined plane ascending around a central axis. (Figure 149.) The

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projection of the plane from the axis is called the thread. The plane moves the distance between the threads in making one turn around the axis. A spiral staircase is a machine of this kind. The screw is another example of a gain in power with a corresponding loss in distance. The screw, generally combined with the lever, is used in many ordinary machines. The jackscrew (Figure 150), copy-press, and vise are examples of combinations of these two simple machines.



FIGURE 150

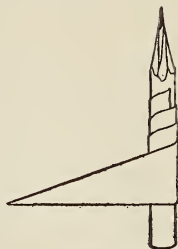


FIGURE 149

II. THE STEAM ENGINE, THE GAS ENGINE, AND THE AUTOMOBILE

Man's Most Important Energy Transformers.—Perhaps the first of nature's forces that man made use of was the wind. He hoisted a sail for the wind to strike upon and to push him from place to place. About the twelfth century A. D. he discovered a way of arranging sails upon a wheel, thus constructing a windmill to help him in his work. The windmill is still used in some places where small power is needed, but the wind is no longer one of man's main sources of energy.

Running water early impressed man with its power. He finally harnessed this power for grinding his grain and for



AN ANCIENT SAILBOAT

doing other kinds of work by means of the water wheel. Many shapes of wheels were tried before the mighty water turbine, such as is used at Niagara Falls, was invented. The electric dynamo and the electric motor, which will be discussed later, are energy transformers which man has developed and now uses in connection with the water turbine. It is probable that more power is now developed at these Falls than was developed by all the earlier water wheels ever used.

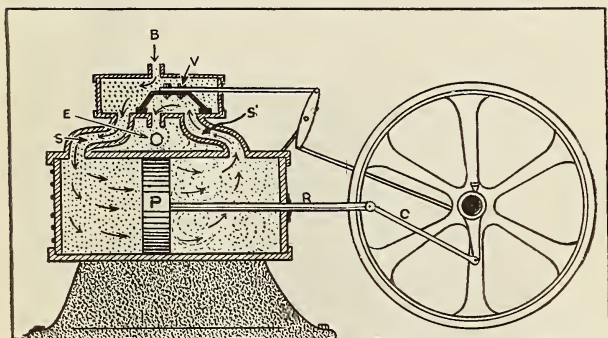


FIGURE 151.—DIAGRAM SHOWING WORKING PARTS OF STEAM ENGINE

About the middle of the eighteenth century, a young Scotchman, James Watt, invented a machine to utilize the power of expanding steam. He arranged a cylinder containing a piston so that the steam would be admitted alternately on one side and then on the other side of the piston.

How the back and forth movement of the piston is converted into rotary motion can best be understood by an examination of the accompanying diagram. (Figure 151.)

The Steam Engine.—The essential parts of a steam engine are the *boiler* and the *engine*. It is sometimes

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convenient to locate these near each other, as in a railway locomotive; and sometimes, as in factories, at a distance from each other.

Heat generated in the firebox changes the water into steam. The expanding steam forces its way through a pipe to the parts of the engine where heat energy is to be transformed into mechanical energy (page 78).

Refer now to Figure 151. The steam, coming from



Courtesy Illinois Central Railway

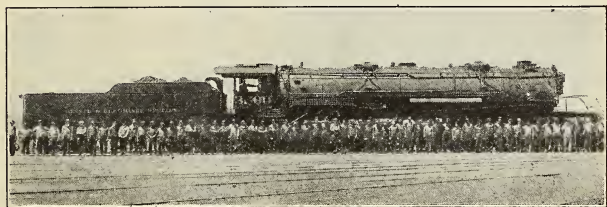
ONE OF THE FIRST STEAM LOCOMOTIVES IN THE WEST

the boiler through the pipe (*B*) is passing through the steam channel *S* into the cylinder, and is forcing the piston *P* to the right. Its motion is conveyed by the piston-rod *R* and the connecting-rod *C* to the drive-wheel or fly-wheel. The steam that is in the cylinder to the right of the piston is being forced out by way of the steam-channel *S*, under the slide-valve *V*, to the exhaust *E*.

Just as the edge of the piston reaches the steam channel

So the slide valve is automatically moved to the left to cover the steam channel *S*. The steam; now entering the channel *S'*, drives the piston to the left. Thus the backward and forward movements of the piston follow in rapid succession, and the motion is conveyed by some such device as is indicated to the turning of a drive-wheel or a fly-wheel.

Water in the boiler must be steadily replenished to take the place of the escaping steam. Various automatic devices are employed to accomplish this, but possibly the



Wide World Photo

MONSTER LOCOMOTIVE

This locomotive is for freight service in the mountains. It stands almost 16 feet high, and its length is more than 105 feet. When loaded it weighs 744,000 pounds.

most satisfactory of these is the one which condenses the steam from the exhaust and pumps it back into the boiler.

The Steam Turbine.—In recent years inventors have made it possible to apply steam under great pressure to a wheel somewhat similar in construction to a water turbine. Thus steam is made to give a rotary motion, instead of the back and forth motion of the ordinary steam engine, which must be converted into rotary motion by the connecting rod and crank. These steam turbines, as they are called, have been used to great advantage in ocean vessels where there is little space available for machinery and where great power and high speed are desired.

The Gas Engine.—The gas engine is the product of the last half century but its widespread use in the automobile, truck, and tractor has come since 1900.

The gas engine differs from the steam engine first in that the actual combustion takes place not in a separate firebox but inside the engine itself. Hence the gas engine is called an internal combustion engine. The energy of the gas engine comes from gases exploding and expanding under heat.

We have learned (pages 95–99) that if a fuel gas be com-

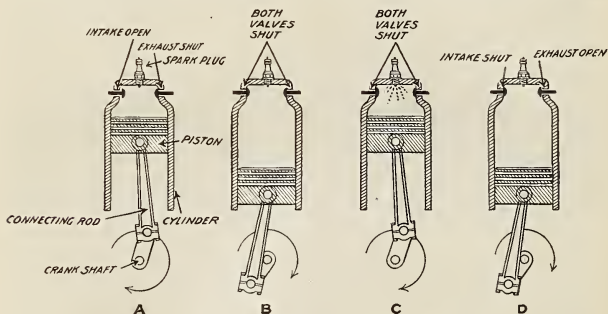


FIGURE 152.—DIAGRAM SHOWING THE FOUR STROKES OF A GAS ENGINE

bined with the right proportion of air, it forms an explosive mixture. Since in the gas engine the explosion occurs in a closed *cylinder*, a gas engine must be provided with a device for vaporizing gasoline and mixing it with air. Such a device is called a *carburetor*. The principle of the carburetor is as simple as that of the devices shown on pages 97 and 98, but the construction of the modern carburetor is somewhat complicated.

The action in a cylinder of a gas engine is shown in detail by the four accompanying diagrams. Suppose that a *piston* is in the position shown in Figure 152, A. If now the *crank-shaft* (Figures 152, A and 153) be turned to the

right, as in starting a car by hand, the piston will descend, creating a partial vacuum in the cylinder. Atmospheric pressure will thus force the explosive mixture from the carburetor through a set of pipes and the *intake valve* into the cylinder.

As the piston reaches its lowest point in the cylinder, and is about to start upward again, the intake valve closes (Figure 152, B). Thus the ascending piston compresses the explosive mixture to about one-fourth its original volume.

Figure 152, C, shows the piston again at its highest point, with the gas compressed. Just as it is ready to descend, a spark passing from point to point of the *spark plug* ignites the mixture and the explosion drives the piston back to its lowest point. The gas engine is now running under its own power.



Wide World Photo

FIRST DELIVERY OF MAIL BY AIR FROM SAN FRANCISCO TO NEW YORK

Pilot C. Eugene Johnson delivers a special delivery package mailed the day before.

As the *connecting rod* is now carried around and drives the piston upward, the *exhaust valve* opens (Figure 152, D), and the burned gases are driven out by the ascending piston. When it reaches the top of this stroke, it will be ready to descend again "sucking in" an explosive mixture for another firing.

Thus for every explosion of a gas-engine cylinder, there are four strokes, two upward and two downward.

The Automobile Engine.—In an automobile engine there are at least four of these cylinders firing in rapid

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succession and exerting their power on the crank-shaft. The greater the number of cylinders, the more frequently is power exerted on the crank-shaft and the less jerky is the motion of the car. Thus a six-cylinder or an eight-cylinder car runs more smoothly than a four-cylinder car.

The accompanying diagram (Figure 153) illustrates the relative positions of the pistons of a four-cylinder automobile engine, and shows by what means their power is

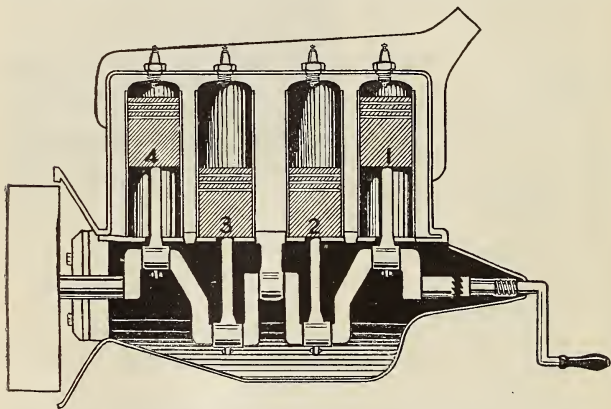
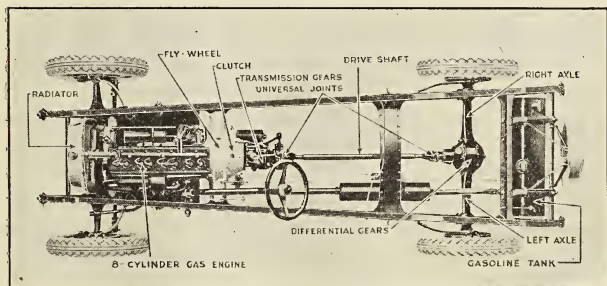


FIGURE 153.—CROSS SECTION OF FOUR-CYLINDER AUTOMOBILE ENGINE

exerted on the crank-shaft. Piston 1 has just compressed the explosive mixture and is ready to be fired. Piston 2 has just been fired and is at the bottom of its downward stroke. Piston 3 has just "sucked in" an explosive mixture and will compress it on the next upward stroke. Piston 4 has just forced out the burned gases, ready on its next downward stroke to take in the explosive mixture. The order of firing of this engine is therefore 1,3,4,2. Trace it with the aid of the foregoing explanation.

Lubrication and Cooling.—It is most important that all friction surfaces be sufficiently oiled with lubricants of the right sort. Constant action combined with the heat of combustion make it necessary to keep the pistons and the cylinder walls well lubricated during every moment of running. Automobile engines have provisions for automatic oiling of these parts, provided only the driver knows enough to keep oil in the *crank-case* (Figure 153).

But no amount of oil could prevent a gas engine from destroying itself if it were not for the cooling system.



Courtesy Hupp Motor Car Corporation

FIGURE 154.—CHASSIS OF AN EIGHT-CYLINDER AUTOMOBILE

In some engines, this cooling of the cylinders is accomplished by circulating air around them; but in most cars water is circulated around the cylinders. As the water, heated by the cylinders, passes through the *radiator*, it is cooled. Continuous circulation of the water, gathering heat from the cylinders and losing it in the radiator, keeps the engine from becoming overheated.

Transmission of Power in an Automobile.—In the steam engine, the energy of expanding steam is exerted steadily. An engineer, by allowing the steam from his

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boiler to enter the cylinder of the engine slowly, may start a locomotive smoothly on its way.

But an automobile engine is different. At best its energy is exerted not steadily but in successive explosions. Attached to the crank-shaft of an automobile, therefore, is a heavy *fly-wheel*. When this is set going, it tends by its own inertia (page 39) to keep going steadily and to make the turning of the crank-shaft smooth instead of jerky.

Because of the necessity of steadying the jerky motion of the gas engine by first setting the heavy fly-wheel in motion, the engine crank-shaft is disconnected during starting from the shaft which drives the car (*drive-shaft*, Figure 154). When the fly-wheel has been set going rapidly enough, the crank-shaft of the engine is connected with the drive-shaft of the car by means of a *clutch*—which may be connected or disconnected by a simple motion of the foot.

Here again a set of devices is made necessary by the inertia of the heavy car itself. These devices are called *transmission gears*. (Figure 154.) They are toothed wheels of different sizes, contained in a gear case. We have learned that a heavy body cannot be easily started nor easily stopped. Provision is, therefore, made by means of the gears to start a heavy car slowly.

This is done by the driver's shifting the gear lever into "low gear." In low gear, the engine crank-shaft is connected with the drive-shaft through the smallest of the toothed wheels, or gears. By this arrangement, the crank-shaft turns several times while the drive-shaft turns once. This affords very great power but very slow speed. In starting a car, therefore, the driver first sets his engine going, then "shifts into low gear," and finally connects the clutch. After the heavy car has been set in motion, the driver may shift to *intermediate* and then to *high* gear.

When the shift has been made to high gear, the drive-shaft is running at the same speed as the engine crank-shaft.

The drive-shaft extends from the transmission gears to another set of gears contained in a case midway between the two rear wheels. These are called the *differential gears* (Figure 154). The drive-shaft is turned by the transmission gears and conveys this motion to the differential gears, which turn the *rear axle*. The drive-shaft is not a solid shaft of steel running from one set of gears to the other. If it were, it would frequently be broken by the jouncing of the car over uneven roads. It is connected with one set of gears—and sometimes with both—by a *universal joint* (Figure 154). At such a joint, the drive-shaft yields in any direction without breaking when it is jarred.

The rear axle is divided. The gears which turn this divided axle are called differential gears, because they are so arranged as to turn one-half of the axle at a different rate of speed from the other when necessary. Thus in turning a corner, the differential gears make it possible for the half of the rear axle which turns the outer wheel to rotate more rapidly than the half which turns the inner wheel.

SUMMARY

Man's intellect has enabled him to use his energy in many intricate ways and to multiply his strength many-fold by the contrivance and use of simple tools and machines. The simple machines are the lever, the wheel and axle, the pulley, the inclined plane, the wedge, and the screw. A general statement of the law of all these machines is that what is gained in power is lost in speed, and what is gained in speed is lost in power.

All complex machines are made up of combinations of simple machines. The invention of complex machines is responsible for the existence of large cities, of manufacturing on a large scale, of rapid transportation,

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and of the conveniences that make modern life so comfortable.

The steam engine is a complex machine that makes use of the power of expanding steam. The basic thing in the construction of the steam engine is the piston, so arranged that steam is admitted alternately to one side of it and then to the other. The back and forth movement of the piston is converted into rotary motion by means of levers.

In the gas engine, the energy of gases exploding and expanding under heat is used to produce motion. The gas engine is called an internal combustion engine because the actual burning of fuel occurs inside a closed cylinder. An automobile engine is made up of four or more cylinders, and the power is applied by means of levers to a crank-shaft.

By means of a fly-wheel, the motion of the crank-shaft is steadied. A clutch connects the transmission line of the car itself with the fly-wheel. Provision is made in the transmission line of the car for starting the car slowly so as to avoid strain, for guarding against breakage when the car is jouncing over uneven roads, and for turning corners with the greatest ease.

QUESTIONS

Tell something of the work of various kinds of machines in the field of transportation.

What is friction and how do we overcome it in the running of machines?

What are the six simple machines? Explain the advantage of each of these simple machines.

What is a brief statement of the law of simple machines?

With the aid of the figure in this text, explain the operation of a steam engine. What is a steam turbine?

With the aid of the figures given in this chapter, explain the operation of a gas engine.

Why are lubrication and cooling necessary?

With the aid of the figure given in this chapter, explain what is meant by transmission of power in the automobile.

CHAPTER XIX

ELECTRICITY IN MODERN LIFE

By means of electricity, the world of matter has become a great nerve, vibrating thousands of miles in a breathless point of time.—Hawthorne.

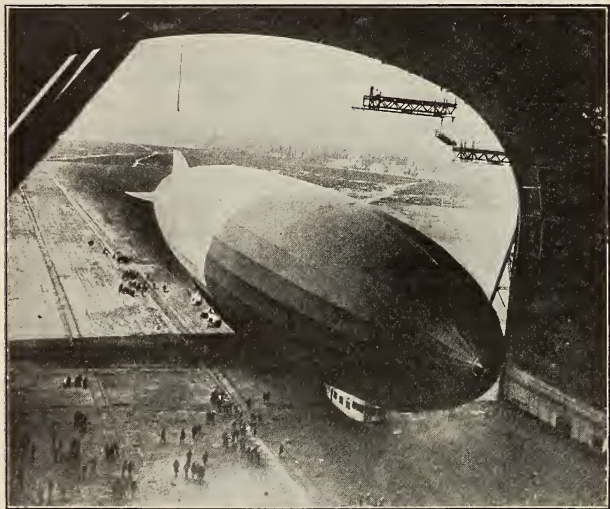
There is a tradition to the effect that Thales, the earliest of the old Greek philosophers, discovered electricity about 600 B.C. Certainly electricity has been known for many centuries as a form of energy. But less than a century has passed since man first harnessed it for practical service.

The story is told that on the morning of December 21, 1879, the managing editor of the New York *Herald* came rushing into the office three hours earlier than usual and excitedly sought the city editor. All a-tremble he pointed to a prominent article on the front page of that morning's *Herald*. "How did that stuff get into the paper?" he shouted. "Lights in bottles strung on wires, indeed! You've made a laughing stock of the *Herald*. That kind of light is against the laws of nature." This editorial storm was caused by the fact that the *Herald* that morning had been the only paper to carry the great news of Edison's invention of the incandescent electric light.

This was almost a half century ago. Since then electricity has almost revolutionized modern life. If the dwellers in cities were suddenly to be deprived of the uses of electricity, they would be nothing short of panic-stricken. Street-cars, automobiles, and trucks would

stop dead. People could not get to their work. Power would be cut off from hundreds of factories. Industry and commerce would be paralyzed.

Deliveries of the necessities of life by thousands of trucks would cease. Food prices would go soaring. Night



Pacific and Atlantic Photo

THE LOS ANGELES

The giant airship is being maneuvered into the airdrome at Lakehurst, N. J., which it shared with the Shenandoah. The Los Angeles established a new record for sustained flight. Its first 5000 miles over land and sea were traveled at the rate of about $62\frac{1}{2}$ miles an hour.

would shroud homes, business buildings, and streets in darkness. Communication with the outside world by telephone, telegraph, and radio would cease. Even the airplane and the dirigible would not be left to us as messengers.

The employment of electrical energy is now so much a

part of our everyday life that it is impossible for us to imagine how we could get along without it. Certainly it is most important that we should know something of this form of energy and of how man has put it to work.

I. ELECTRICITY AS FIRST KNOWN

Electricity by Friction.—It was known by the ancient Greeks that when certain substances, one of which was amber, were rubbed, they had the power of attracting light objects. This property was afterward called electricity, from the Greek word for amber.

Experiment 156.—Place some small pieces of paper or pith balls on a table and after rubbing a glass rod with silk bring it near the pieces. Do the same with a stick of sealing wax or a hard rubber rod rubbed with flannel or a cat's skin. Note the action of the pieces.

Experiment 157.—Rub a glass rod briskly with silk and place in a wire sling such as is shown in Figure 155. Bring toward one end of the glass rod another glass rod which has been rubbed with silk. Do the rods attract or repel each other? Bring toward the suspended rod a piece of sealing wax or a vulcanite rod which has been rubbed with flannel or a cat's skin. Does this repel or attract the glass rod?



FIGURE 155

Experiment 158.—Suspend a pith ball by a silk thread from the ring of a ringstand. Rub a glass rod with a piece of silk and bring it near the pith ball but do not allow the two to touch. Note the action of the ball. Touch the pith ball with the rod. Does it behave now as it did before? Rub a vulcanite rod with a piece of flannel or cat's skin and bring it near a suspended pith ball. Does the pith ball act as it did with the glass rod? Touch the pith ball with the rod. How does it act? Bring a glass rod rubbed with silk near a pith ball which has been in contact with a vulcanite rod after it was rubbed with flannel or a cat's skin. Does the glass rod repel or attract the ball?

Experiment 159.—Suspend a pith ball from the ring of a ringstand by a very fine piece of copper wire no larger than a thread. Wrap the wire around the pith ball in several directions. Bring a rubbed glass rod toward the pith ball. Does it act as it did when suspended

by silk? Allow the ball to touch the rod. Does the ball now act as it did when suspended by silk? Try these same experiments, using the vulcanite rod.

From the previous experiments it has been seen that when glass is rubbed with silk, and vulcanite with flannel or a cat's skin, they seem to have two different kinds of electrical charges. The like kinds repel each other and the

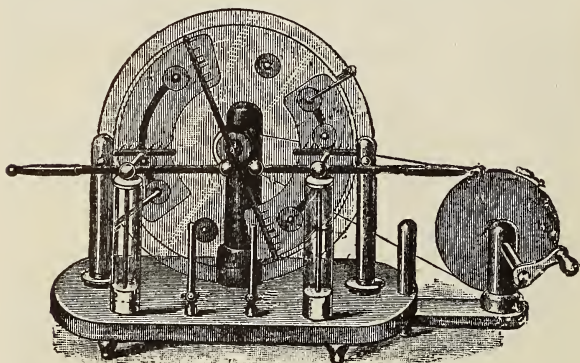


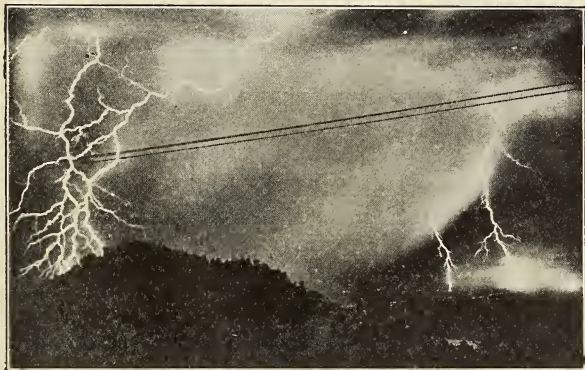
FIGURE 156

opposite kinds attract. These two kinds are called *positive* and *negative* respectively.

Whether there are really two kinds of electricity has not yet been fully determined, but electricity acts exactly as it would if there were two kinds, and it has become customary to speak as if there were. In Experiment 158 it was found that pith balls suspended by a silk thread could be charged with electricity if brought in contact with a charged body. Experiment 159 showed that this was not possible when they were suspended by a copper wire. The wire conducted the electricity away. Substances like copper that conduct electricity are called conductors, and

those substances like silk which will not conduct it, non-conductors.

Experiment 160.—Having started the electrical action in a static electrical machine (Figure 156), pull the knobs as far apart as the spark will jump and notice the course taken by the spark. Does it travel in a straight line? Hold a piece of cardboard between the knobs so that its edge is just within the line joining them. What effect does the cardboard have upon the direction taken by the spark? Place the cardboard so that it entirely covers one of the knobs. Is



A FLASH OF LIGHTNING

An electrical discharge between clouds and the earth.

the spark able to pass through the card? Attach a wire with a sharp point to each of the knobs and extend it vertically two or three inches above the knob. Start the machine. Do sparks now jump across between the knobs? Why are houses provided with lightning rods?

About the middle of the eighteenth century, Benjamin Franklin proved by his notable kite experiment that lightning was simply an electrical discharge between the clouds and the earth, or between different clouds. This discharge is similar to that which takes place on an electrical machine. The electricity in the clouds attracts as close as

possible the opposite kind of electricity on the earth's surface and tends to hold it accumulated on high objects. If the attraction is sufficient, the electricity discharges between the cloud and the object, and we say the object was struck by lightning.

If a sharp point, such as a lightning-rod, is present on the object where the electricity tends to accumulate, it allows the electricity to pass off gradually before enough accumulates to cause damage. Lightning-rods, however, must be continuous conductors and properly terminated in the ground.

II. SERVICEABLE ELECTRICAL ENERGY

In Experiments 156 to 160, muscular energy was transformed into electrical energy. In none of these cases, however, could the electrical energy have been made of practical service to man. Methods of producing electrical energy under different conditions had to be found before this form of energy could be made to do work.

Current Electricity.—In Experiment 159 it was found that it was impossible to charge the pith ball when it was suspended by the copper wire. The electricity passed off, was conducted away, through the wire. We had here a current of electricity through the wire, but it was only for an instant. At the opening of the nineteenth century, an Italian by the name of Volta discovered how a continuous electric current could be produced. If a strip of zinc and a strip of copper or carbon are placed in dilute sulphuric acid and connected with a wire (Figure 157), a current of electricity will flow through the wire from the copper or carbon to the zinc. The current is due to the chemical action of the sulphuric acid on the zinc. Chemical energy has been transformed into electrical energy.

An arrangement such as that shown in Figure 157 is

called a voltaic cell, after its discoverer. In a cell of this kind, hydrogen bubbles formed by the action of the acid on the zinc soon collect on the copper strip, and the current weakens and finally stops. The cell is then said to be polarized. If cells are to be of practical value, they must not quickly polarize; that is, a way must be found to get rid of the hydrogen bubbles. This is generally done by putting some substance into the cell that will unite with the hydrogen and thus keep the copper strip free of hydrogen bubbles. Many kinds of cells have been invented which do not readily polarize.

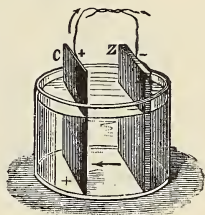


FIGURE 157

The so-called dry cell (Figure 158) is most used at the present time. It consists of a zinc can lined on the inside with porous paper. In the center is a carbon rod. Packed around the carbon and filling the can is usually a moist mixture of sal ammoniac, manganese dioxide, granulated carbon, plaster of Paris, and generally small quantities of other materials. In this cell the sal ammoniac acts upon the zinc somewhat as the sulphuric acid did in the simple cell first mentioned. The manganese dioxide unites chemically with the hydrogen bubbles and thus removes them from the carbon rod. The plaster of Paris keeps the cell in rigid shape and the granulated carbon helps to keep the contents porous so that action may go on freely within the cell.

FIGURE
158

In voltaic cells the copper or carbon strip is called the positive electrode or pole, and the zinc is called the negative electrode or pole.

Experiment 161.—Connect a positive and a negative pole of two $1\frac{1}{2}$ volt dry cells by a fairly heavy copper wire. Attach a similar piece of wire to each of the other poles and connect these pieces by means

of a short, very fine, iron wire. (Figure 159.) The iron wire will become red hot. Now remove the fine iron wire and connect the loose ends of the copper wires to a small socket containing an incandescent lamp of about 3 volts—the kind of lamp that is used in the ordinary flashlight. (Figure 160.)

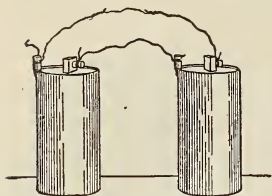


FIGURE 159

Trace this current in the experiment just performed. If a broken incandescent lamp is at hand, the circuit may be traced through the lamp itself.

If the circuit be broken at any point, the current will cease. Since in any circuit it is frequently necessary to break the circuit and thus to discontinue the current, special devices known as *switches* are made to serve this purpose. Switches are always convenient, but they are also essential for safety in breaking a circuit through which a large current is flowing. Obtain if possible an ordinary knife-switch and see how the current passes through it when it is closed.

In Experiment 161, the iron wire was reddened by the heat and the incandescent lamp was made to glow. We found that when the current flowed through the very fine iron wire or the very fine filament of the incandescent lamp,

The first thing that appears from this experiment is that in order to have a current of electricity, we must have a complete path or *circuit* for it. Trace this current in the ex-

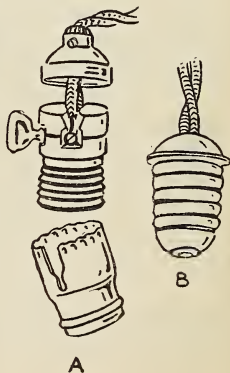


DIAGRAM SHOWING HOW WIRES ARE ATTACHED TO AN INCANDESCENT LIGHT SOCKET

some of the electrical energy was transformed into heat energy. A thin wire offers more resistance to the flow of the electric current than a heavy wire. Certain materials heat up more quickly than others in the electric current for the same reason. Short wires offer less resistance than long wires.

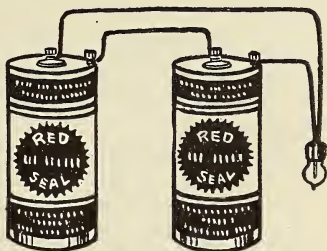
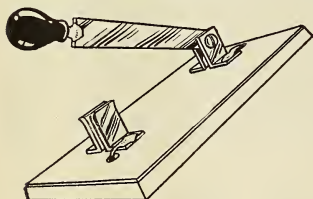


FIGURE 160

Force of an Electric Current.—Water at the faucet is under a certain number of pounds of pressure (p. 242). This pressure has nothing to do with the size of the stream. For example, you may open the faucet only slightly and get a very small stream of water or you may open it wide and get a full stream. The pressure behind both streams is the same. What corresponds to pressure in a stream of electricity is called *electromotive force* and is measured in volts. The most common “pressure” or voltage for a lighting circuit is from 110 to 120 volts.



A KNIFE-SWITCH

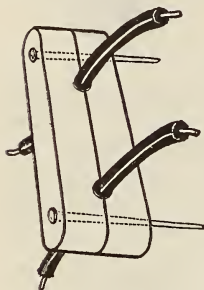
The farther a current must travel, the higher must be its voltage. Through power transmission wires the electric current is forced under a pressure of thousands of volts. The electromotive force of a small dry battery such as is shown in Figure

158 is $1\frac{1}{2}$ volts. When two of these are connected as in Experiment 161, the electromotive force is three volts. The best lamp for a three-volt circuit is a three-volt lamp.

Lamps and fixtures are made to carry currents of definite electromotive force.

To illustrate: Six-volt batteries are most common for automobiles. A six-volt incandescent lamp is made for use on a current from such a battery. On a three-volt circuit such as is employed in Experiment 161, this light would hardly glow. But if it were connected to the 110-volt lighting circuit of your home the filament would be instantly destroyed.

Dangers and Safeguards in an Electric Circuit.—To keep a current of electricity within the circuit designed for it, wires are covered with non-conducting substances, called *insulators*. Rubber, cotton, and silk are used for this purpose. Porcelain and glass are used for insulating purposes in attaching electric wires to their supports.



PORCELAIN INSULATORS

If the insulation on two or more parts of a circuit is broken and a piece of metal connects two of these exposed parts of a circuit, a *short circuit* results. In such a case, so much current flows through the wires that they may be melted in two. To avoid the burning out of wires or fixtures on an electric circuit, *fuses* are used. (Figure 161.) A fuse is a device for breaking the circuit automatically when there is danger of the wires being overheated. The metal of the fuse forms part of the circuit and this metal melts at a much lower temperature than any of the wires in the circuit.

Electric Lighting.—The little electric lamp used in Experiment 161 (Figure 162), like most other incandescent lamps consists of a thread or filament of carbon inclosed in a glass bulb from which the air has been exhausted. When this lamp is connected with an electric current the carbon is

heated white hot by the resistance it offers to the electric current. The carbon cannot burn because there is no air in the bulb, and it does not melt since there is not sufficient heat to accomplish this. Incandescent



FIGURE 161

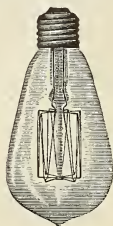
lamps are also made with metal filaments. Only two metals, tantalum and tungsten, have been found that will withstand the intense heat. Incandescent lamp filaments made from these metals are nec-



FIGURE 162

essarily much longer and thinner than the carbon filaments, and are therefore more easily broken. But their great advantage lies in the fact that they use less than one-third the amount of current in giving the same light. A tungsten filament will withstand much heavier jarring when it is hot than when cold. The relative efficiency of carbon and tungsten lamps is shown on page 374.

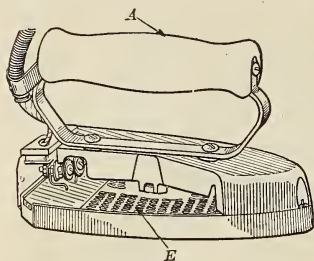
It sometimes happens that a lamp has imperfections that render it dangerous to handle carelessly. If one touches the metal part of such a lamp when it is in use on a high voltage circuit, especially with wet hands, one is likely to receive a severe shock. These shocks have sometimes proved fatal. To avoid such possible danger one should touch only the hard-rubber switch in turning a light on or off. Especial care should be taken when the hands are wet, because moisture is an excellent conductor of an electrical current.

TUNGSTEN
LAMP

Other Devices That Make Use of Heat of Resistance.—Heating caused by resistance of an electric current is utilized in the construction of electric flatirons, toasters, stoves, and other devices. The electricity is generally conducted to the utensils through a wire made up of a number of small copper wires

covered with non-conducting materials. The resistance of the connecting cord is very low. From this cord, the

current passes through coils in the utensil that offer high resistance. These are so arranged that the resulting heat is delivered with almost no loss to the surface which is to be heated. Although it costs more to produce the same amount of heat by electricity than it does by the other methods usually em-



ELECTRIC IRON SHOWING HEATING ELEMENT (E)

ployed in the home, yet for many purposes this heat can be applied with so little loss that the use of electricity in some kinds of heating becomes not only convenient but also really economical.

Heat generated by electricity is also used for welding (Figure 163), and is beginning to replace the forge. If metal rods are pressed together end to end and a sufficiently great current of electricity is sent through them, the heat generated at the point of contact, where the resistance is greatest, will be sufficient to weld them together. The rails of car tracks are often welded together in this way.

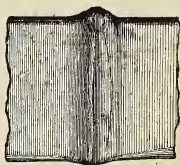
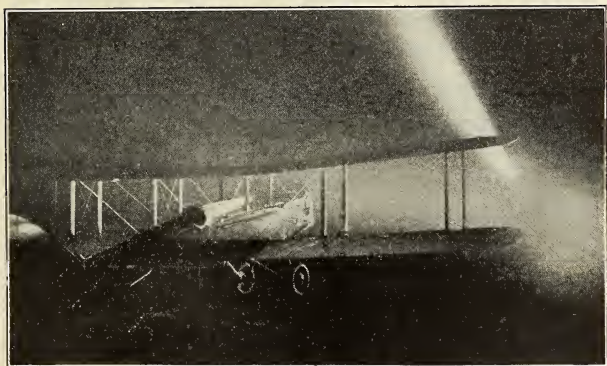


FIGURE 163
WELDED IRON

Measuring the Electric Current and Computing the Cost.—The electric stream may vary in size as does a stream of water. We speak of a stream of water as running so many gallons per second. The size of the electric current we measure in amperes. For example, only a small stream of one-half

ampere is required to run a 60-watt incandescent lamp, but a large stream of five amperes is necessary to run an electric iron.

It is in connection with the size of the stream of electricity in a house that fuses serve the purpose of safety devices. For example, suppose your electric company has a 15-ampere fuse on your dining room circuit. Now suppose you are operating on this circuit two 60-watt incan-



Underwood and Underwood

A REVOLVING FOUR-MILLION CANDLE-POWER ELECTRIC BEACON

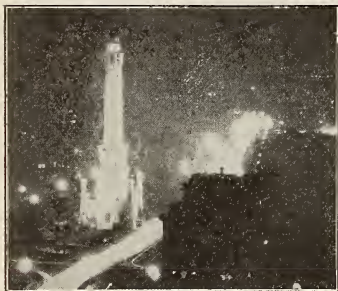
Each landing field for U. S. Mail aircraft is equipped with these beacons. Their light can be seen for 100 miles as it sweeps the sky.

descent lamps, each requiring one-half ampere; and a toaster and a chafing-dish, each requiring 5 amperes. This makes a total of 11 amperes. If now you add a percolator, requiring 5 amperes, all the devices on the circuit together would demand a current of 16 amperes, and the overstrain would melt the 15-ampere fuse on that circuit.

The remedy is to put in a new 15-ampere fuse, and not to use so many devices on the circuit at the same time.

Or it may be that the company will allow you a 20-ampere fuse on that circuit, so that you may use all the devices at the same time. But do not use fuses of larger amperage without the consent of your electric company, because your wiring may not safely carry a larger stream. If the fuse should be of larger amperage than the wiring would carry, an overload would burn out the wiring instead of the fuse. There must always be a safe margin between the size of stream your wiring will carry and the size of stream your fuses will withstand.

The amount of water flowing from a faucet depends on



Courtesy Marshall L. Brown

NIGHT TURNED INTO DAY BY MODERN
ELECTRIC LIGHTING

A photograph of Michigan Avenue, Chicago,
from the 14th floor of the Allerton Club.

the size of the stream and the pressure behind it. The amount of electric current flowing through a wire depends on the size of the current (amperage), and the "pressure," or voltage. This power is measured in watts. The number of watts may be determined accurately for direct current by simply multiplying the number of amperes by the number of volts. For exam-

ple, an electric iron using a current of 5 amperes under pressure of 110 volts requires 550 watts of electrical energy to keep it heated. If this iron is used for an hour, we say that it consumes 550 watt-hours of current.

But a watt-hour indicates so small an amount of current that the commercial unit of measurement is the kilowatt-hour, 1000 watts for an hour's time. Another way of putting it is that 1 kilowatt-hour = 1000 watt-hours.

Your electric fixtures are marked with the number of amperes and volts necessary to run them. The iron mentioned above would be marked "5 amperes, 110 volts." In an hour's time this would consume 550 watt-hours of current, as has been shown. This is $\frac{550}{1000}$, or .55, kilowatt-hour. If your company charges 10c. a kilowatt-hour, it costs you $.55 \times \$1.0$, or \$.055, to operate your electric iron for an hour.

An electric stove with all the switches open requires an electric stream of about 20 amperes. On a 110-volt current such a stove in full operation would consume in an hour 2200 watt-hours of current. This is $\frac{2200}{1000}$, or 2.2, kilowatt-hours. At 10c. a kilowatt-hour, such an electric stove, with all the "burners" going, would cost $2.2 \times \$1.0$, or \$.22 an hour.

An incandescent lamp marked 40 watts indicates that it uses 40 watts of current per hour. A 40-watt incandescent lamp would therefore burn 25 hours ($1000 \div 40$) before it registered 1 kilowatt-hour, or 10c. worth of current.

Reading the electric meter, or watt-hour meter (as it is



KILOWATT HOURS

DIAL OF A WATT-HOUR METER

The reading is 538 kilowatt-hours. The circles from right to left record units, tens, hundreds, thousands.

called) is exactly the same as reading the water meter, except that the unit is kilowatt-hours, and the 100,000 circle is missing. Beginning at the right, and reading to the left, the circles indicate units, tens, hundreds, thou-

sands. The dial in the accompanying figure reads 538 kilowatt-hours.

Notice that the hand in the tens circle is in a doubtful position. It must be read 30 because the hand in the unit circle has not yet reached 0.

Class Assignment.—Make a diagram of your electric meter reading at home, bring it to class, and tell how many kilowatt-hours it indicates. What rates are charged by your local electric company for current? Tell how much it costs per hour to operate some electric appliance in your home.

Chemical Effect of an Electric Current.—Electroplating.—**Experiment 162.**—Almost fill a dish with a strong solution of copper sulphate (blue vitriol). Across the dish and a little distance apart, place two parallel wooden rods. Carefully clean with fine sandpaper a strip of lead and a strip of copper. Punch a hole in an end of each strip and attach to each strip two or three feet of fairly heavy copper wire. Pinch the wires firmly on to the copper and lead at the points of connection. Suspend a strip from each of the rods by winding the wire once around the rod. Attach the wire from the copper to the positive pole of a battery and the wire from the lead to the negative pole. A copper plate will be deposited on the lead.

In Experiment 162, the copper solution is decomposed by the electric current as it passes through the solution from the copper strip to the lead strip, and the copper freed from the compound is deposited on the lead. Just as fast as copper from the solution is deposited on the lead strip, the same amount of copper is dissolved from the copper strip; and so the strength of the solution is maintained as long as there is any of the copper strip remaining. If it were desired to plate with silver, a silver strip would have to be substituted for the copper strip and a solution of a suitable silver compound substituted for the copper sulphate solution. Whatever the metal used for plating, corresponding solutions would have to be used. All gold, silver, nickel and other plating is done in this way.

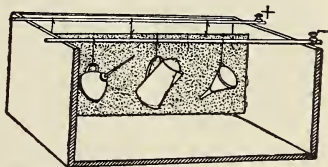


Underwood and Underwood

WRECKING DISCARDED WARSHIPS

Warships that were discarded in accordance with the Washington Disarmament Treaty were taken to Alexandria, Virginia. Here they were destroyed by the method shown. A great steel ball weighing two tons is lifted 75 feet by a giant electromagnet. The current is then turned off and the huge ball drops, crushing the hull beneath.

This book, like all books made in large numbers, has been printed from electrotype plates. First a page was set up in type, and then a careful impression of it was taken in wax. Wax is not a good conductor of electricity and so the face of the wax mold was evenly and thinly coated with graphite in order to make it conduct electricity. The graphite-covered mold was then attached to the negative electric pole, as was the lead in Experiment 162, and immersed in the copper sulphate solution. To the positive pole was attached a copper strip. As soon as a layer of copper of the thickness of a calling-card had been deposited on the mold, taking its shape, the newly formed copper plate was separated from the wax impression and was "backed up" with type metal to make it strong enough to be used in the printing press. The illustration on the opposite page is from a photograph of the electrotype from which this page was printed; look at it in a mirror.



SIMPLE APPARATUS FOR ELECTROPLATING

III. MAGNETISM AND ELECTRICITY YOKED FOR SERVICE

Magnetism.—In very ancient times pieces of iron ore were found which had the property of attracting iron. Such pieces of ore are called loadstones. Artificial loadstones are called magnets.



FIGURE 164

The discovery that a bar of loadstone or a magnetic needle, if floated or freely suspended (Figure 164), will invariably assume a definite position was made in the Far East at a very early date. It was supposed even up to the time of the first voyage of Columbus that the magnetic needle

always pointed toward the North Star or perhaps at some place a little to the east of it. The sailors of Columbus were greatly alarmed when they found as they sailed west that the needle swung off to the west of the true north.



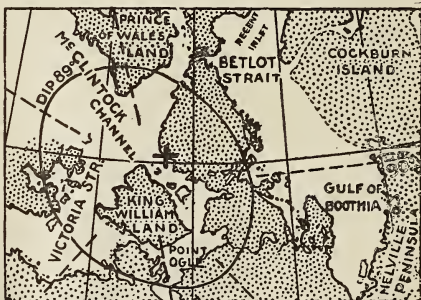
MARINER'S COMPASS

We know now that the north end of the needle does not point toward the north geographical pole as was at first supposed, but toward a point in the southwestern part of Boothia Felix which is called the north magnetic pole.

The south magnetic pole as recently determined is a little to the east of Victoria Land.

Permanent Magnets.—Experiment 163.—Touch with each end of a bar magnet small pieces of paper, copper, zinc, iron, sawdust, and any other materials that may be handy. Which substances are attracted by the magnet? Does it make any difference which end is used? Take a knife blade that has no such attractive power and rub it several times along one end of the magnet; then touch the different substances with it. Has it acquired any new power?

Experiment 164.—Suspend a bar magnet horizontally in a sling made from a bent piece of wire (Figure 155). Bring one of the ends of another bar magnet toward it. What is the

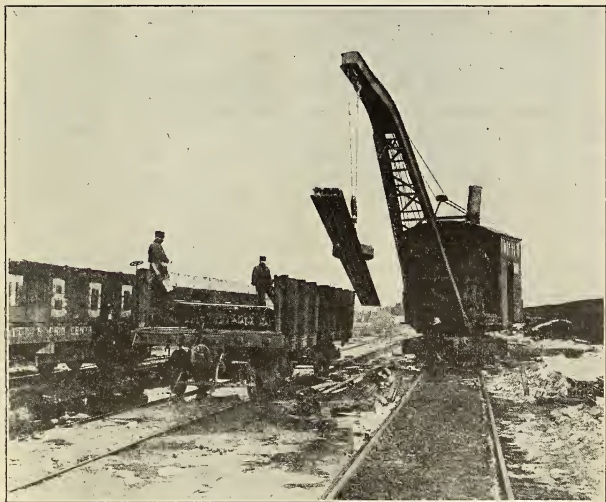


LOCATION OF THE NORTH MAGNETIC POLE

Boothia Felix is a peninsula, the north tip of which is the northernmost extension of the American continent. It was discovered by Sir John Ross on his most famous exploring voyage. His nephew, Sir James Clark Ross, afterward (June 1, 1831) located the northern magnetic pole at approximately 70° N. lat. and 97° W. long. Locate it on the map of Canada.

effect? Reverse the ends of the magnet: is there any change in the position of the suspended magnet? Bring a large, soft iron nail toward either end of the suspended magnet. What is the effect? Reverse the ends of the nail. (Be careful that the nail has not become permanently affected by the magnet.) Is the effect the same as when the ends of the magnet were reversed?

Bring pieces of copper, zinc, and other substances toward the magnet. Do these affect it? Notice that the ends of the bar magnet are marked. What can you state about the attraction or repulsion of



Courtesy of Illinois Central Railroad

ELECTROMAGNETIC CRANE

Loading steel rails on a freight car. The magnet is lifting seven rails, a burden of about three and one-half tons of steel.

similar ends of magnets? Of opposite ends? Does it make any difference in its effect on the suspended magnet toward which the nail is brought? What substances do you find attracted by the magnet?

To the end of a small nail hanging by attraction to a magnet bring another nail. How does the first nail act in respect to the second?

It was early discovered that when pieces of steel were rubbed on a loadstone they took on the properties of the loadstone and became magnets. In the experiments with magnets, it was found that like poles repelled and unlike poles attracted, and that iron or steel in contact with a magnet becomes magnetized. Iron and steel are practically the only substances attracted by a magnet, although nickel and cobalt and a few other substances have a little attraction. Thus steel and iron are always used for magnets.

The Magnetic Field of Force.—Experiment 165.—Place a plate of window glass about 8 x 10 inches above a bar magnet and carefully sprinkle iron filings over it. Describe the behavior of the filings. Sketch on a piece of paper their arrangement. Move a small compass about above the glass plate and note the directions the needle assumes. How do the actions of the needle and of the filings compare? If feasible make a blue print of the filings.

Holding the small compass two or three inches above the magnet move it parallel with the magnet from end to end. Gently tap the compass occasionally so that the needle will move freely. How does the needle act when it is over the ends of the magnet? How does the direction of the compass needle compare with the direction of the bar magnet?

In the experiment just performed we found that when iron filings were sprinkled above the magnet they arranged themselves in definite lines. The small compass needle also arranged itself along these lines when brought under the influence of the magnet. There is, then, around a magnet a magnetic field of force which affects magnets and magnetic substances brought within it.

Electromagnets.—Experiment 166.—Wind several feet of No. 20 insulated copper wire around the nail used in Experiment 164 as you would wind thread on a spool. Attach the ends of this wire to the poles of a dry cell. Bring the nail thus arranged toward a suspended magnet. Reverse the ends of the nail. Does the nail act as it did before it was placed within the coil of wire connected to the

battery? Bring another nail in contact with its ends. What happens? What has the nail as arranged become? Disconnect one of the wires from the battery and try the test again. Does the nail act as it did when the battery was connected?

We found that if a nail is placed in a coil of wire connected with an electric battery (Figure 165) it becomes magnetic, but only as long as the connection is maintained. Magnets of this kind are called *electromagnets*. If the nail had been hard steel and the battery exceedingly strong, the steel would have remained a magnet after being taken out of the coil.

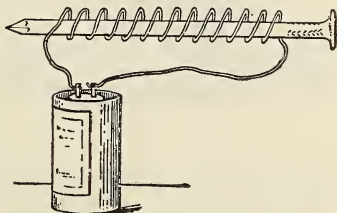


FIGURE 165

Electromagnets have come to be of almost inestimable use in modern life. The telegraph, the telephone, the magnetic crane, the electric motor, and very many other mechanical devices are dependent largely upon the principle of *electromagnetism* for their usefulness.

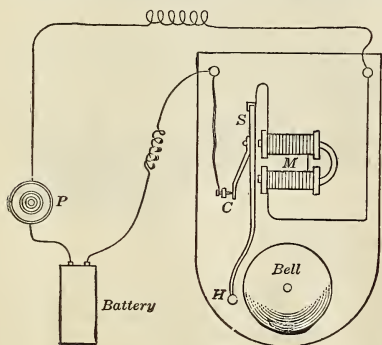


FIGURE 166.—ELECTRIC BELL

The Electric Bell.
—One of the simplest applications of the electromagnet is the electric bell (Figure 166). When the punch-button *P* is pushed down it closes the circuit through the electro-

magnet *M*. The hammer *H* is then attracted toward the magnet, and as it moves toward it the circuit is broken at *C*. Because of this break the current no longer flows

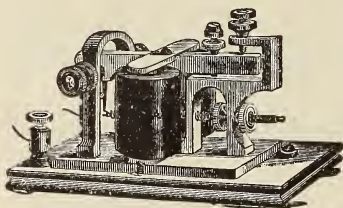


FIGURE 167

through *M* and the soft iron cores instantly lose their magnetic power. Since the hammer is no longer attracted to *M*, it is thrown back by the spring *S* to its original position, thus closing the circuit again and reestablishing magnetic attraction at *M*.

This alternate closing and breaking of the circuit at *C* goes on so rapidly that the successive taps of the clapper on the bell blur into an almost continuous sound. As soon as the button *P* is released, the circuit is broken at that point and the bell ceases ringing.

The Electric Telegraph.—In 1832 an American, Samuel F. B. Morse, invented the commercial telegraph. This was the first step in the wonderful progress that has been made during the last century in communicating rapidly between distant points. The necessary instruments used in this form of communication are a sounder (Figure 167) and a key (Figure 168). The following experiment illustrates the arrangement and operation of a simple telegraph.



FIGURE 168

Telegraphic Communication.—

Experiment 167.—Attach one end of a wire to a pole of a dry cell and the other end to one of the binding posts of a telegraphic sounder. From the other binding post of the sounder lead a wire to a binding post of a telegraphic key. Connect the free binding post of the key with the free pole of the battery

(Figure 169). When the key is pushed down, the circuit is closed and the sounder clicks. If a relay can be procured, remove the sounder and connect two of the binding posts of the relay in the same way that the sounder was connected.

Connect one of the free binding posts of the relay with a binding post of the sounder and the other binding post with the pole of a dry cell. Connect the other pole of the dry cell with the free binding post of the sounder. When the key closes the circuit through the relay, the circuit through the sounder and its dry cell is closed by the relay (Figure 170), and the sounder clicks. This is the usual arrangement in a simple telegraph office. The sounder in the first

part of the above experiment can be replaced by an electric bell (Figure 171) and the key by a push button, thus showing the arrangement of the ordinary doorbell.

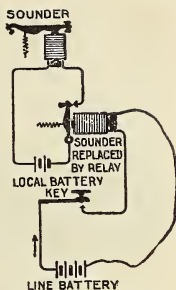


FIGURE 169

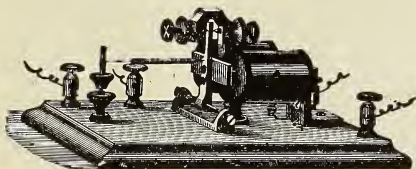


FIGURE 170

The sounder is simply an electromagnet such as was made in Experiment 166, arranged to attract a piece of soft iron held at a short distance from it by a spring. When this piece of iron is attracted toward the magnet, it strikes on another piece of iron, making a click, and so remains drawn to the magnet as long as the circuit is kept closed. Thus long and short clicks can be made. Morse arranged a combination of these long and short clicks to rep-

resent letters of the alphabet. This system of communication is called Morse code. The sounder is simply an electromagnet such as was made in Experiment 166, arranged to attract a piece of soft iron held at a short distance from it by a spring. When this piece of iron is attracted toward the magnet, it strikes on another piece of iron, making a click, and so remains drawn to the magnet as long as the circuit is kept closed. Thus long and short clicks can be made. Morse arranged a combination of these long and short clicks to rep-



FIGURE 171

resent the alphabet. Thus he was able to send words from one station to another.

Many improvements have been made since Morse first sent a dispatch between Washington and Baltimore, but his dot-and-dash alphabet and the electromagnet sounder and the key are still in use.



FIGURE 172

Since 1832, the land has been strung with telegraph wires and the ocean girdled with cables, and now an important event occurring in

any part of the earth is known almost instantly in all other parts. The telephone, the wireless telegraph, and the wireless telephone, all electrical devices, have added to the ease of communication so that the whole earth is brought into such close relation that every part may know what is happening elsewhere.

The Greatest Electrical Discovery.—In 1831, Michael Faraday, an English physicist, made a discovery the results of which have almost revolutionized civilized man's industrial life. He found that when a magnet is quickly thrust into a coil of wire a momentary electrical current is generated in the wire, and when the magnet is removed a momentary current is generated in the opposite direction. The same effect is produced if the strength of the magnet in the coil is quickly increased or decreased, or if the coil is revolved between the poles of a magnet. This discovery makes it possible to transform mechanical energy into electrical energy and is responsible for the invention of the dynamo, the motor, and many other electrical devices.

The Telephone.—In 1875 Alexander Graham Bell first communicated by telephone from Boston to Cambridge, a distance of only a few miles. To-day man can talk

across the continent. Probably no device has resulted in greater saving of time.

The simple telephone (Figure 173) consists of a hard-rubber case in which is a permanent bar magnet sur-



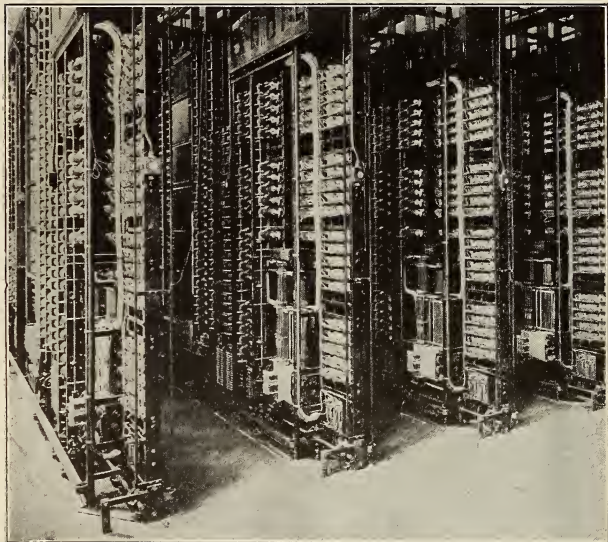
Courtesy New York Telephone Company

GIRLS OPERATING TELEPHONE SWITCHBOARDS

rounded at the end by a coil of fine wire. In front of the magnet, and almost touching it, is mounted a thin iron disk. Above this a concave rubber cap with a hole in the center completes the case. The ends of the coil of wire are connected with the wires from the coil of another

instrument of the same kind. One of the wires from each coil may be connected with the ground.

The sound waves from the voice (or from any other source) cause the disk to vibrate back and forth in front of the magnet. These rapid vibrations of the disk result



Courtesy New York Telephone Company

AUTOMATIC MACHINES FOR TELEPHONE SWITCHING

Machines of this type are gradually taking the place of an army of girls.

in correspondingly rapid changes in the strength of the magnet, and momentary electrical currents are induced in the coil of wire. These electrical impulses flow to the coil of wire in the other instrument, where they cause correspondingly rapid changes in the strength of the permanent bar magnet of that instrument. The rapid variations of strength of this magnet cause the disk in front

of it to vibrate in the same way that the first disk vibrated and thus to throw out sound waves similar to those of the speaker's voice. The sound is in no sense transmitted. The sound waves are transformed into electrical impulses which are transmitted to the other instrument, where they are again transformed into sound waves.



FIGURE
173

For complicated modern telephone systems, a different instrument is used for transmitting (Figure 174), but the principle involved is the same. The

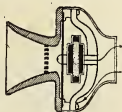
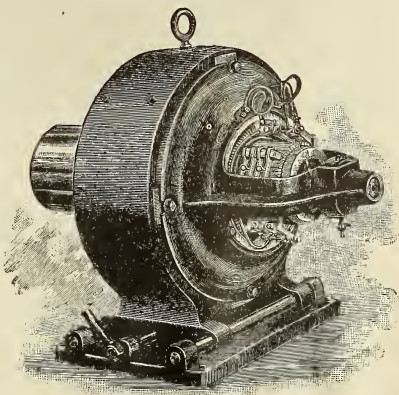


FIGURE 174

instrument described is still used for receiving, except that the bar magnet has been replaced by a U-shaped magnet.

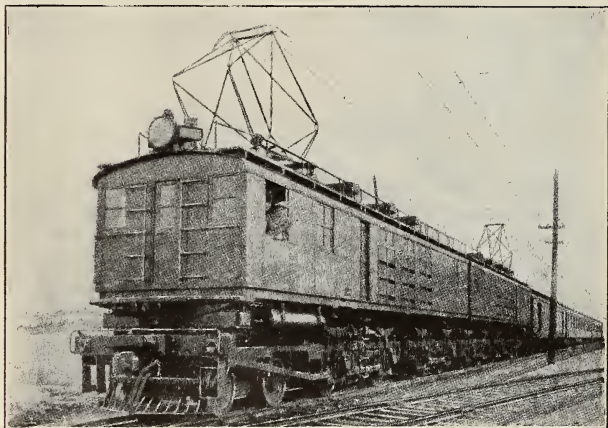
The Dynamo.—The dynamo is a profoundly important result of Faraday's discovery. In the dynamo, coils of wire are revolved between strong magnetic poles, and the currents of electricity which are generated are collected and delivered to the line wire to be used wherever desired. In commercial machines, there are usually several pairs of electromagnets and many coils of wire. The coils are revolved by means of water-power, steam-power, or any other available power.

The electricity that is generated by the dynamo is



DYNAMO

easily transferred by wires to a long distance from the point where it is generated. Los Angeles uses electrical power which is generated in the mountains over 300 miles away. The energy of the water falling at Niagara is transformed into electrical energy which is utilized for transportation and for industrial purposes at a distance of nearly 200 miles. The location of the power no longer determines



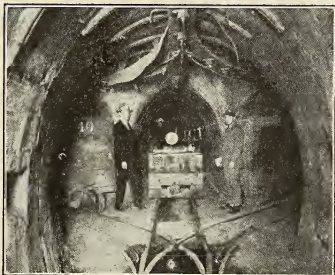
Courtesy of Chicago, Milwaukee and St. Paul Railway
ELECTRIC LOCOMOTIVE

the site of a factory. The factory may be located at the most convenient place possible and be run by power which is transmitted from almost inaccessible mountain retreats.

The Electric Motor.—In the dynamo the coils of wire are revolved in a magnetic field by some mechanical power, and electricity is generated in the coils. In the motor the process is reversed; electricity is passed through the coils of the motor. This causes them to revolve in a magnetic field and to produce mechanical power. In appearance

and make-up the two machines are similar, but their work is different. The dynamo generates an electrical current; the motor uses an electrical current.

In the running of the ordinary street car, the motor and the dynamo supplement each other. At the power house are dynamos run by any convenient kind of mechanical power. The electricity that is generated is collected and transmitted by wires and trolley through the controller to the motor under the street car. The motor-man, by means of the controller, is able to turn the current into the motor or to shut it off. When the current is turned on, the motor revolves; by gearings the motion is imparted to the wheels and the car moves. Thus the electricity generated by the dynamos in power houses, wherever they may be, not only lights our homes and streets, but also enables the little motors in our homes, the powerful motors on street cars, and the giant motors of our factories to do all kinds of work for us.



Courtesy Chicago Daily News

UNDERGROUND FREIGHT

Electric transportation makes possible rapid freight service underground. This is the corner of State and Madison Streets, Chicago, 60 feet underground. The city has a sixty-seven mile system of freight subways.

Theory of Electricity.—A great deal is known about how electricity acts and what it does, but as yet little is known about what it really is. Recent experiments indicate that the atoms of matter (page 60) contain electricity, and that the negative electricity in them exists in the form of exceedingly minute particles called electrons. There

are hundreds of these electrons in each atom, and they are held there probably by the attraction of a positive charge of electricity at the center of the atom. If the positive and negative charges in the atoms of a body are equal, the body is unelectrified.

If, however, the electrons are in any way joggled off and accumulated, a negative charge of electricity develops where this accumulation takes place. As the electrons are all negative, they repel one another and tend to move away from the point where they have accumulated to places where the accumulation is not so great. This is what happened in Experiment 160, when the electrical machine was used. An electric current is supposed to be a stream of these electrons.

All Forms of Energy Are Related.—In this chapter we have learned that there is a close relation between the two forms of energy known as magnetism and electricity. The transformation of electrical energy into chemical energy (Experiments 161 and 162) shows a relation between those two forms. Careful experiments by many scientists have proved that there is a very close relation between all forms of energy; and a surprising kinship between energy and matter, as is indicated by the foregoing comments on the theory of electricity.

It was seen in Experiment 15 that when white light is passed through a prism, it is not only refracted but it is also separated into different colors. Very accurate experiments have shown that light consists of waves and that the infinitesimally small wave-lengths of the various colors differ in length from one another. The rate of travel of all these waves of light, no matter how different in length, is 186,000 miles a second.

Scientists, by means of delicate devices, have been able to measure the wave-lengths of light with absolute accu-

racy. The longest wave-lengths of light that make any impression on the eye are those of deep red. A deep-red wave measures slightly less than $\frac{1}{36000}$ of an inch from crest to crest. The shortest wave-lengths that make any impression on the eye are those of violet. Violet waves are a little more than half as long as the deep-red waves. Between these two extremes range the other colors in the order indicated by the old memory-word, *vibgyor*: violet, indigo, blue, green, yellow, orange, red.

There are waves of radiant energy longer than the deep-red waves and shorter than the violet waves, but they make no impression on the eye. If you heat a poker tip slightly and hold it near your hand, you will feel radiant energy coming from it in the form of heat. The *waves of heat energy*

are much longer than the deep-red rays—so long that they make no impression on the retina. If you heat the poker tip more, it will become red. The molecules of iron have been put into such rapid motion that some of the wave-lengths of energy radiating from the poker tip are now short enough to affect the retina.

There are still longer waves than heat waves. These



Courtesy Chicago Daily News

CHICAGO LISTENING TO WASHINGTON, D. C.

Crowd in Grant Park, Chicago, listening to a speech by President Coolidge transmitted 1000 miles by radio.

are called *electro-magnetic* waves—the waves of radio and wireless telegraphy. They are so long that they may be measured in meters or even in miles.

Rays of energy with waves too short to affect the eye are called *ultra-violet* (meaning, beyond the violet). These rays which the eye can not detect are the only ones which affect a photographic plate. Beyond the violet, wave-lengths range down to those of the X-Ray, which are so infinitesimally short that they can pass even between atoms of stone or of human flesh.

And so we see that electro-magnetic waves, heat-waves, color waves, the invisible ultra-violet waves, and *X-Rays* are all related forms of energy, ranged on a scale of varying wave-length.

SUMMARY

Electricity has been known for many centuries as a form of energy, but less than a century has passed since man first harnessed it for practical service. The employment of electrical energy is now so much a part of our everyday life that it is impossible for us to imagine how we could get along without it.

It was known by the ancient Greeks that when certain substances were rubbed they had the power of attracting light objects. There seemed to be two kinds of electrical charges. The like kinds repel each other and the opposite kinds attract. These two kinds are called positive and negative. Benjamin Franklin proved by his kite experiment that lightning was simply an electrical discharge between the clouds and the earth, or between different clouds.

It was not known, however, until the opening of the nineteenth century how a continuous electric current could be produced. The discovery of how to produce an electric

current made it possible to use electrical energy for various purposes.

The heating effect of electric currents is used in electric lighting, in the construction of electric flat irons, toasters, stoves, and other devices. Heat generated by the electrical current is also used for welding.

The chemical effect of an electric current also has many applications in commerce and industry. All gold, silver, nickel, and other plating is done with the aid of electrical current. Electrotypes plates which have made printing on a large scale much more economical, are produced by means of the chemical effects of the electrical current.

The yoking of magnetism and electricity make possible a very wide use of electrical energy. This yoking finds application in the electric bell, electric telegraph, the telephone, the dynamo, and the electric motor.

QUESTIONS

What would be some of the results in city life if we should be cut off from all use of electricity?

What was the first form of electricity known?

Why could electrical energy, as it was first known, not be put to use?

What was Volta's great discovery? }

How is a dry cell constructed?

What is meant by an electrical circuit? What is the purpose of switches?

In what units is the amount of an electrical current measured?

What are insulators? What is meant by a short circuit?

Describe the incandescent lamp. What other devices make use of the heat of the electrical current?

Explain why we use fuses on an electrical circuit that carries a heavy charge.

What is the method of electroplating?

What is an electro-magnet? In what devices for communication does it find application?

What was Faraday's great discovery? How far-reaching have been the results of that discovery?

APPENDIX

I. PHYSICAL MEASUREMENTS

Units.—To measure any physical quantity, a certain definite amount of the same kind of quantity is used as the *unit*. For example, to measure the length of a body, some arbitrary length, as a foot, is chosen as the unit of length; *the length of a body is the number of times this unit is contained in the longest dimension of the body*. The unit is always expressed in giving the magnitude of any physical quantity; the other part of the expression is the numerical value. For example, *60 feet, 500 pounds, 45 seconds*.

In like manner, to measure a surface, the unit, or standard surface, must be given, such as a square foot; and to measure a volume, the unit must be a given volume, such, for example, as a cubic inch, a quart, or a gallon.

Systems of Measurement.—Commercial transactions in most civilized countries are carried on by a decimal system of money, in which all the multiples are ten. It has the advantage of great convenience, for all numerical operations in it are the same as those for abstract numbers in the decimal system. The system of weights and measures in use in the British Isles and in the United States is not a decimal system, and is neither rational nor convenient. On the other hand, most of the other civilized nations of the world within the last fifty years have adopted the *metric system*, in which the relations are all expressed by some power of *ten*. The metric system is in well-nigh universal use for scientific purposes. It furnishes a com-

mon numerical language and greatly reduces the labor of computation.

Measure of Length.—In the metric system the unit of length is the *meter*. In the United States it is the distance between two transverse lines on each of two bars of platinum-iridium at the temperature of melting ice. These bars, which are called “national prototypes,” were made by an international commission and were selected by lot after two others had been chosen as the “international prototypes” for preservation in the international laboratory on neutral ground at Sèvres near Paris. Our national prototypes are preserved at the Bureau of Standards in Washington. The two ends of one of them are shown below. The only multiple of the meter in general use is



ENDS OF METER BAR

the *kilometer*, equal to 1000 meters. It is used to measure such distances as are expressed in miles in the English system.

The Common Units in the Metric System are:

1 kilometer (km.)	= 1000 meters (m.)
1 meter	= 100 centimeters (cm.)
1 centimeter	= 10 millimeters (mm.)

The Common Units in the English System are:

1 mile (mi.)	= 5280 feet (ft.)
1 yard (yd.)	= 3 feet
1 foot	= 12 inches (in.)

By Act of Congress in 1866 the legal value of the yard is $\frac{3600}{3937}$ meter; conversely the meter is equal to 39.37 inches. The inch is, therefore, equal to 2.540 centimeters.

The unit of length in the English system for the United States is the *yard*, defined as above. The relation between the centimeter scale and the inch is shown below.

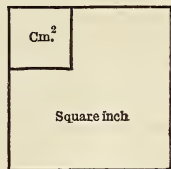
$$100 \text{ MILLIMETERS} = 10 \text{ CENTIMETERS} = 1 \text{ DECIMETER} = 3.937 \text{ INCHES.}$$



INCHES AND TENTHS

CENTIMETER AND INCH SCALES

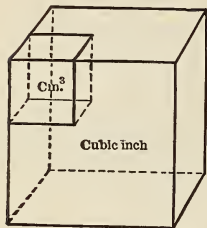
Measures of Surface.—In the metric system the unit of area used in the laboratory is the square centimeter (cm.^2). It is the area of a square the edge of which is one centimeter. The square meter (m.^2) is often employed as a larger unit of area. In the English system both the square inch and the square foot are in common use. Small areas are measured in square inches while the area of a floor and that of a house lot are given in square feet; larger land areas are in acres, 640 of which are contained in a square mile.

SQUARE CENTIMETER
AND SQUARE INCH

The square inch contains $2.54 \times 2.54 = 6.4516$ square centimeters. The relative sizes of the two are shown in the accompanying figure.

The area of regular geometric figures is obtained by computation from their linear dimensions. Thus the area of a rectangle or of a parallelogram is equal to the product of its base and its altitude ($A = b \times h$); the area of a triangle is half the product of its base and its altitude ($A = \frac{1}{2}b \times h$); the area of a circle is the product of 3.1416 (very nearly $\frac{22}{7}$) and the square of the radius ($A = \pi r^2$); the surface of a sphere is four times the area of a circle through its center ($A = 4 \pi r^2$).

Cubic Measure.—The smaller unit of volume in the metric system is the *cubic centimeter*. It is the volume of a cube the edges of which are one centimeter long. The cubic inch equals $(2.54)^3$ or 16.387 cubic centimeters. The relative sizes of the two units are shown here. In the English system the cubic foot and cubic yard are employed for larger volumes. The cubical capacity of a room or of a freight car would be expressed in cubic feet; the volume of building sand and gravel or of earth embankments, cuts, or fills would be in cubic yards.



CUBIC CENTIMETER AND
CUBIC INCH

The unit of capacity for liquids in the metric system is the *liter*. It is a decimeter cube, that is, 1000 cubic centimeters. The imperial gallon of Great Britain contains about 277.3 cubic inches, and holds 10 pounds of water at a temperature of 62° Fahrenheit. The United States gallon has the capacity of 231 cubic inches.



CYLINDRICAL
GLASS
GRADUATE

Common Units in the Metric System:

- | | |
|----------------------------------|--|
| 1 cubic meter (m. ³) | = 1000 liters (l.) |
| 1 liter | = 1000 cubic centimeters (cm. ³) |

Common Units in the English System:

- | | |
|------------------------|-------------------------------------|
| 1 cubic yard (cu. yd.) | = 27 cubic feet (cu. ft.) |
| 1 cubic foot | = 1728 cubic inches (cu. in.) |
| 1 U. S. gallon (gal.) | = 4 quarts (qt.) = 231 cubic inches |
| 1 quart | = 2 pints (pt.) |

The volume of a regular solid, or of a solid geometrical figure, may be calculated from its linear dimensions. Thus, the number of cubic

feet in a room or in a rectangular block of marble is found by getting the continued product of its length, its breadth, and its height, all measured in feet. The volume of a cylinder is equal to the product of the area of its base (πr^2) and its height, both measured in the same system of units.

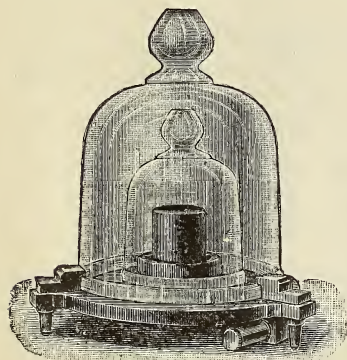
Liquids are measured by means of graduated vessels of metal or of glass. Thus, tin vessels holding a gallon, a quart, or a pint are used for measuring gasoline, sirup, etc. Bottles for acids usually hold either a gallon or a half gallon, and milk bottles contain a quart, a pint, or a half pint. Glass cylindrical graduates and volumetric flasks are used by pharmacists, chemists, and physicists to measure liquids. In the metric system these are graduated in cubic centimeters.



VOLUMETRIC
FLASK

Units of Mass.—The unit of mass in the metric system is the *kilogram*. The United States has two prototype

kilograms made of platinum-iridium and preserved at the Bureau of Standards in Washington. The *gram* is one thousandth of the kilogram. The latter was originally designed to represent the mass of a liter of pure water at 4° C. (centigrade scale.) For practical purposes this is the kilogram. The gram is therefore equal to the mass of a cubic cen-



STANDARD KILOGRAM

timeter of water at the same temperature. The mass of a given body of water can thus be immediately inferred from its volume.

The unit of mass in the English system is the *avoirdupois pound*. The *ton* of 2000 pounds is its chief multiple; its submultiples are the *ounce* and the *grain*. The avoirdupois pound is equal to 16 ounces and to 7000 grains. The "troy pound of the mint" contains 5760 grains. In 1866 the mass of the 5-cent nickel piece was legally fixed at 5 grams; and in 1873 that of the silver half dollar at 12.5 grams. One gram is equal approximately to 15.432 grains. A kilogram is very nearly 2.2 pounds. More exactly, one kilogram equals 2.20462 pounds.

All mail matter transported between the United States and the fifty or more nations signing the International Postal Convention, including Great Britain, is weighed and paid for entirely by metric weight. The single rate upon international letters is applied to the standard weight of 15 grams or fractional part of it. The International Parcels Post limits packages to 5 kilograms; hence the equivalent limit of 11 pounds.

Common Units in the English System:

1 ton (T.)	= 2000 pounds (lb.)
1 pound	= 16 ounces (oz.)
1 ounce	= 437.5 grains (gr.)

Common Units in the Metric System:

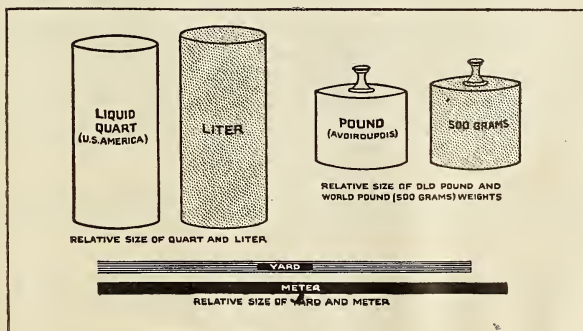
1 kilogram (kg.)	= 1000 grams (g.)
1 gram	= 1000 milligrams (mg.)

The Unit of Time.—The unit of time in universal use in physics and by the people is the *second*. It is $\frac{1}{86400}$ of a mean solar day. The number of seconds between the instant when the sun's center crosses the meridian of any place and the instant of its next passage over the same meridian is not uniform, chiefly because the motion of the earth in its orbit about the sun varies from day to day. The *mean solar day* is the average length of all the variable solar days throughout the year. It is divided into $24 \times$

$60 \times 60 = 86,400$ seconds of mean solar time, the time recorded by clocks and watches. The sidereal day used in astronomy is nearly four minutes shorter than the mean solar day.

The Three Fundamental Units.—Just as the measurement of areas and of volumes reduces simply to the measurement of length, so it has been found that the measurement of most other physical quantities, such as the speed of a ship, the pressure of water in the mains, the energy consumed by an electric lamp, and the horse-power of an engine, may be made in terms of the units of *length*, *mass*, and *time*. For this reason these three are considered *fundamental units* to distinguish them from all others, which are called *derived units*.

The system now in general use in the physical sciences employs the *centimeter* as the unit of length, the *gram* as the unit of mass, and the *second* as the unit of time. It is accordingly known as the *c. g. s.* (centimeter-gram-second) system.



II. BIBLIOGRAPHY

The attempt here made is to present not a complete but a dependable bibliography.

The few books included under the heading "General List" may safely be ordered by any school library. They are all books of proved attractiveness and worth for junior high school students to "browse" in.

The books and bulletins listed by chapters are of much narrower scope, but all very readable. The Farmers' Bulletins and other Government publications may be had from the Superintendent of Documents, Washington, D. C. Much use is made of these bulletins for reports and projects especially in the second half of the book. They are usually simple, up-to-date, and practical.

GENERAL LIST

BOOKS

The Outline of Science, J. Arthur Thompson. G. P. Putnam's Sons, New York. This is a four volume set which covers the whole range of science in fascinating story form. Exceptionally well illustrated.

Our Physical World and *Our Living World*, Elliot R. Downing, University of Chicago Press, Chicago. A widely useful pair of books within the range of the junior high school pupil.

Official Handbook of the Boy Scouts of America. Boy Scouts of America, New York.

A Short History of Natural Science, Buckley. D. Appleton and Company. Old but very useful and interesting.

Masters of Science and Invention, Floyd L. Darrow. Harcourt, Brace and Company. Short stories of the lives of famous inventors and scientists, together with short sketches of their most interesting work.

Keeping Up With Science, Edwin E. Slosson. Harcourt, Brace and Company. Well-told stories of scientific discoveries and inventions from Indian life to the present.

Trees, Stars and Birds, Edwin L. Moseley. World Book Company. Simple, well-written, practical.

Science of Plant Life, Transeau. World Book Company. Interesting, accurate, inexpensive.

MAGAZINES

The Popular Science Monthly, Chicago.

Popular Mechanics, Chicago.

Nature Magazine, American Nature Association, Washington, D. C.

The Mentor, Crowell Publishing Company, Springfield, Ohio.

National Geographic Magazine, Washington, D. C.

CHAPTER LIST

CHAPTER I

The Monthly Evening Star Map, Leon Barritt, 367 Fulton Street, Brooklyn, N. Y.

A Beginners Star Book, Kelvin McKready. G. P. Putnam's Sons.

Barritt—Serviss Star and Planet Finder, Leon Barritt, 367 Fulton Street, Brooklyn, N. Y. A cleverly constructed chart of the heavens, good for any hour of any night of the year.

CHAPTER II

Einstein Theory of Relativity, Garrett P. Serviss. Edwin Miles Fadman, N. Y.

Easy Lessons in Einstein, Edwin E. Slosson. Harcourt, Brace and Company.

The Einstein theories have no place in such a textbook as this. In response to inquiries as to the easiest reference material to be had along this line, the author lists the two foregoing books. These two authors succeed admirably in making clear some of the simpler concepts without involving the reader in mathematical entanglements.

CHAPTER III

The Amateur Chemist, A. F. Collins. D. Appleton and Company. An easy book for any one who is interested in chemistry in everyday life.

CHAPTER V

Fire Prevention and Fire Fighting on the Farm, Farmers' Bulletin 904. 5c.

CHAPTER VI

Farm Home Conveniences, Farmers' Bulletin 927. 5c.

CHAPTER X

Measurements of the Household, Bureau of Standards, Circular No. 55, Superintendent of Documents, Washington, D. C. 15c.

Water Systems for Farm Homes, Farmers' Bulletin 941. 5c.

CHAPTER XI

American Boy's Book of Signs, Signals, and Symbols, Dan Beard. Macmillan Company.

Practical Hints for Amateur Forecasters, P. R. Jameson. Taylor Instrument Company, Rochester, N. Y. An inexpensive little pamphlet that offers a great deal of help to any one who is learning to use meteorological instruments.

Reading the Weather, T. M. Longstreth. Macmillan Company. One of the most readable books on the subject of weather. Clear and simple. Sorts out weather wisdom from silly superstitions.

Why the Weather, Charles F. Brooks. Harcourt, Brace and Company. Excellent book; clearly and accurately written.

CHAPTER XII

Animals of the Past, Frederick A. Lucas. American Museum of Natural History. Here, for example, is told the story of the body of a mammoth (ancient ancestor of the elephant) discovered in Siberia, which had been so perfectly preserved for thousands of years in the ice that the dogs ate the flesh of the animal.

Animals before Man in North America, Frederick A. Lucas. D. Appleton and Company.

Extinct Animals, Sir Edwin Ray Lankester. A. Constable and Company, London.

Mighty Animals, Jennie I. Mix. American Book Company.

Red Book of Animals Stories, Andrew Lang. (Chapter on "When the World Was Young.")

Uncle Sam, Wonder-Worker, Wm. A. Dupuy. Frederick A. Stokes and Company. (Chapter on "Restoring Prehistoric Monsters.")

CHAPTER XIII

The Adventures of a Grain of Dust, Hallam Hawsworth. Charles Scribner's Sons.

Soil Sense. Distributed free to schools on request. International Harvester Company, Chicago.

The Manufacture of Commercial Fertilizers, Bulletin 207, Vermont

Agricultural Experiment Station, Burlington, Vt. This bulletin is about ten years old, but it is easily the best short bulletin obtainable on this subject. Comprehensive, well illustrated.

CHAPTER XIV

Among the best pamphlets on flower, fruit, and vegetable gardening are those issued by certain wholesale dealers in seeds and by the United States Department of Agriculture. A number of books are listed below, with comments as to their nature and degree of usefulness for beginners.

Cultivation of Vegetables

Home Vegetable Gardening, F. F. Rockwell. J. C. Winston Company.

The Home Garden, Eben E. Rexford. J. B. Lippincott Company. These two books are very good guides for the amateur. They deal with vegetable gardening and fruit gardening, furnish useful hints as to the general planning of gardens.

The Home Vegetable Garden, Adolph Kruhm. Orange Judd Company. Treats of each vegetable separately. Designed for the eastern section of the United States.

Home Vegetable Gardening from A to Z, Adolph Kruhm. Doubleday, Page and Company. The same type of book as the preceding, but written with special reference to Pacific Coast conditions.

Home Gardening in the South, Farmers' Bulletin No. 934. 5c. United States Department of Agriculture.

The Farm Garden in the North, Farmers' Bulletin No. 937. 5c.

The City and Suburban Vegetable Garden, Farmers' Bulletin No. 936. 5c.

Cultivation of Fruits

Growing Fruit for Home Use, Farmers' Bulletin No. 1001. 5c.

Making a Garden of Small Fruits, F. F. Rockwell. McBride, Nast and Company.

Home Vegetable Gardening (Part III), F. F. Rockwell. J. C. Winston Company.

The Home Garden (Chapters XIV to XVII) Eben E. Rexford. J. B. Lippincott Company.

Cultivation of Flowers

A-B-C of Gardening, Eben E. Rexford. Harper and Brothers. A very simple and useful book on flower culture.

Yard and Garden, Tarkington Baker. Bobbs-Merrill Company.

On the care of lawn, flowers, vines, shrubs, and trees. A good all-around book for the amateur.

Manual of Gardening, L. H. Bailey. Macmillan Company. A larger book than either of the two preceding. It treats of the care of the lawn, ornamental plants, shrubs, and trees, and devotes a chapter each to the growing of small fruits and of vegetables.

CHAPTER XV

Interesting and Useful Guides to the Study of Trees

Trees as Good Citizens, Charles Lathrop Pack. The American Tree Association, 1214 Sixteenth Street, Washington, D. C. \$2.00. It deals with trees and plants from the standpoint of shade and ornamentation, gives directions for planting and growing.

Studies of Trees, J. J. Levison. John Wiley and Sons. This is one of the most satisfactory all-around books for beginners on identification of common trees, choice of shade trees, care of trees and elementary forestry.

The Tree Guide, Julia Ellen Rogers. Doubleday, Page and Company. A convenient pocket-size guide that enables the forest Rambler to identify trees by their foliage.

Forestry in Nature Study, Farmers' Bulletin No. 468. 5c. Contains a key to 45 of the most common trees.

Books Available for Study of Trees in Various Sections of the United States

Trees of the Northern United States, Austin C. Apgar. American Book Company.

Trees and How to Know Them, W. A. Lambeth. B. F. Johnson Publishing Company, Richmond, Virginia. Identifies the principal forest trees of the South.

The Trees of California, Willis Linn Jepson. H. S. Crocker and Company, San Francisco.

The Following Are More Extensive Tree Guides for All Sections of the United States

Field Book of American Trees and Shrubs, F. Schuyler Mathews. G. P. Putnam's Sons.

The Tree Book, Julia Ellen Rogers. Doubleday, Page and Company.

Manual of the Trees of North America, C. S. Sprague. Houghton, Mifflin Company.

Weeds and Wild Flowers

Testing Farm Seeds in the Home and in the Rural School, Farmers' Bulletin No. 428. 5c.

Weeds and How to Control Them, Farmers' Bulletin No. 660. 5c.

Weed Studies, J. R. Waldron. North Dakota Agricultural College, Bulletin No. 62. Experiment Station (Fargo).

Field Book of American Wild Flowers, F. Schuyler Mathews. G. P. Putnam's Sons. This is the most satisfactory handbook for the identification of wild flowers. Its abundance of illustrations makes it particularly useful to the beginner or amateur.

Wild Flowers Every Child Should Know, Frederic William Stack. Doubleday, Page and Company. A valuable feature of this book for the beginner is its arrangement of the most common wild flowers according to color.

Wild Flowers of the North American Mountains, Julia W. Henshaw. Robert M. McBride Company. This is a beautiful guide to the flowers of the Rockies.

Field Book of Western Wild Flowers, Margaret Armstrong. G. P. Putnam's Sons. A very satisfactory guide to the wild flowers of the regions west of the Rockies.

Flower Guide, Chester A. Reed. Doubleday, Page and Company. A pocket-size guide illustrated in color for the forest Rambler.

Practical Studies of Dependent Plant Life

Destroy the Common Barberry Shrub, Farmers' Bulletin No. 1058. 5c.

Smuts of Wheat, Oats, Barley, and Corn, Farmers' Bulletin No. 507. 5c.

Home Canning of Fruits and Vegetables, Farmers' Bulletin No. 1211. 5c.

Time Table for Canning of Fruits and Vegetables, Miscellaneous Circular No. 24, Department of Agriculture, Washington, D. C. 5c.

Directions for Examining all Canned Foods before Use, Miscellaneous Circular No. 25, Department of Agriculture, Washington, D. C. 5c.

Care of Food in the Home, Farmers' Bulletin No. 1374. 5c.

Milk and Its Use in the Home, Farmers' Bulletin No. 1359. 5c.

CHAPTER XVI

Insect Studies

The Life of the Bee, Maeterlinck. Dodd, Mead and Company, New York. This is a recognized classic.

How to Detect Outbreaks of Insects and Save the Crops, Farmers' Bulletin No. 835. 5c.

Some Insects Injurious to the Vegetable Crops, Farmers' Bulletin No. 33, New Series, Bureau of Entomology. 10c.

Control of Diseases and Insect Enemies of the Home Vegetable Garden, Farmers' Bulletin No. 856. 5c.

Gipsy Moth and Brown-tail Moth with Suggestions for Their Control, Farmers' Bulletin No. 564. 5c.

The Control of the Codling Moth, Apple Scabs, Farmers' Bulletin No. 247. 5c.

San Jose or Chinese Scale, Bulletin No. 62, New Series, Bureau of Entomology. 5c.

Bees, E. F. Phillips. Farmers' Bulletin No. 447. 5c.

Some Facts about Malaria, Farmers' Bulletin No. 450. 5c.

The Yellow Fever Mosquito, Farmers' Bulletin No. 547. 5c.

Remedies and Preventatives Against Mosquitoes, Farmers' Bulletin No. 444. 5c.

The Housefly and How to Suppress It, Farmers' Bulletin No. 1408. 5c.

Bird Studies:—Farmers' Bulletins, 5c. each

No. 493. *The English Sparrow as a Pest.*

506. *Foods of Some Well-Known Birds of Forest, Farm and Garden.*

513. *Fifty Common Birds of Farm and Orchard.*

609. *Birdhouses and How to Build Them.*

621. *How to Attract Birds in Northwestern United States.*

630. *Some Common Birds Useful to the Farmer.*

755. *Common Birds of Southeastern United States in Relation to Agriculture.*

760. *How to Attract Birds in Northeastern United States.*

844. *How to Attract Birds in the Middle Atlantic States.*

912. *How to Attract Birds in the East-Central States.*

Bulletins of United States Bureau of Biological Survey. 5c each.
No. 34. *Birds of California.*

38. *Birds of Arkansas.*

Reliable and Usable Manuals for the Identification of North American Birds

What Bird Is That? Frank M. Chapman. D. Appleton and Company. This is the most usable handbook of birds for the United States east of the Rocky Mountains. Every land bird in that section

is pictured in color. The color plates group the birds according to season, and indicate the relative sizes of birds. The accompanying text is simple but thoroughly adequate. This is not an expensive book.

Color Key to North American Birds, Frank M. Chapman. D. Appleton and Company. The title indicates the character of this book. It is a guide to bird study throughout the North American continent.

Birds of the Rockies, Leander S. Keyser. A. C. McClurg and Company.

Birds of California, Irene Grosvenor Wheelock. A. C. McClurg and Company.

Fighting the Rat

For fighting rats on farms, Farmers' Bulletin No. 896 (5c) offers a wide range of sound advice. See also Bulletin No. 33, Biological Survey.

CHAPTER XVII

How to Live, Fisher and Fisk. Funk and Wagnalls, N. Y.

Handbook of Health, Woods Hutchinson. Houghton-Mifflin Company.

First Aid for Boys, Cole and Ernst. D. Appleton and Company.

American Red Cross Textbook on Elementary Hygiene and Home Care of the Sick, J. A. Delano. P. Blakiston's Son and Company.

How to Select Foods; What the Body Needs, Farmers' Bulletin No. 808. 5c.

CHAPTER XVIII

Victories of the Engineers, Archibald Williams. Thomas Nelson and Sons, New York.

CHAPTER XIX

The American Boys' Book of Electricity, Charles H. Seaver. Davis McKay, Philadelphia.

Harpers' Electricity Book for Boys, Joseph H. Adams. Harper and Brothers.

Two of the most interesting and practical books on electricity for beginners.

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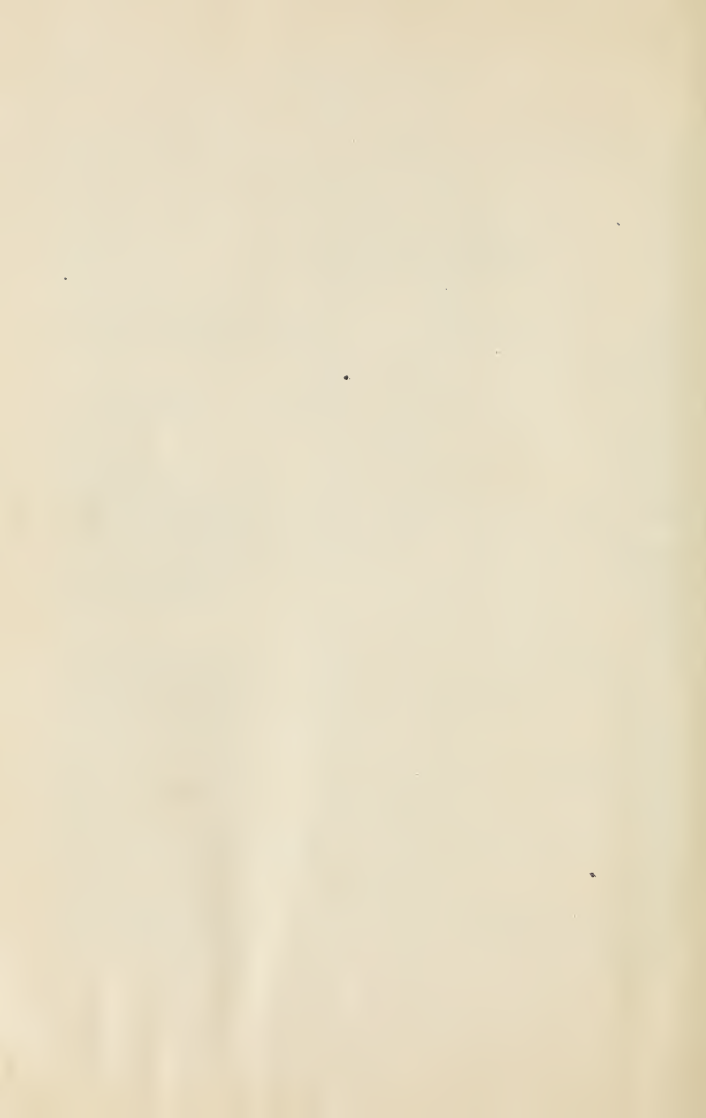
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